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MONTEREY, CALIFORNIA

THESIS

AN INFORMATION ARCHITECTURE FOR THE NAVAL POSTGRADUATE SCHOOL ENTERPRISE

by

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September, 1994

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The advent of personal computers, workstations, and multiple interconnected Local Area Networks at the Naval Postgraduate School (NPS), Monterey, California, has resulted in significant distribution, redundancy, and fragmentation of the data elements and databases necessary to effectively manage the organization. This thesis addresses this issue by accomplishing the following two goals. First, it develops a high-level model of the organization's information architecture through the use of the Information Engineering methodology, with automated support from the Texas Instruments' Integrated Computer Aided Software Engineering (I-CASE) tool Information Engineering Facility™ (IEF™). Based on the high-level model it then provides an analysis of data management architecture alternatives to address the current problems. The thesis main recommendation is for the implementation of a client/server information processing architecture at NPS. The enterprise and information architecture analyses provide additional recommendations to improve the current NPS organizational structure.

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ABSTRACT

The advent of personal computers, workstations, and multiple interconnected Local Area Networks at the Naval Postgraduate School (NPS), Monterey, California, has resulted in significant distribution, redundancy, and fragmentation of the data elements and databases necessary to effectively manage the organization. This thesis addresses this issue by accomplishing the following two goals. First, it develops a high-level model of the organization's information architecture through the use of the Information Engineering methodology, with automated support from the Texas Instruments' Integrated Computer Aided Software Engineering (I-CASE) tool Information Engineering Facility™ (IEF™). Based on the high-level model it then provides an analysis of data management architecture alternatives to address the current problems. The thesis main recommendation is for the implementation of a client/server information processing architecture at NPS. The enterprise and information architecture analyses provide additional recommendations to improve the current NPS organizational structure.

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I. THESIS INTRODUCTION

A. PROBLEM DESCRIPTION

The lack of effective data management in a distributed data environment exposes an organization to inconsistent or misleading information -- which in turn can severely hinder decision-making. The Naval Postgraduate School (NPS), Monterey, California, apparently suffers this problem: the advent of personal computers (PC), workstations, and multiple interconnected Local Area Networks (LAN) at NPS results in significant distribution, fragmentation, and redundancy of the data elements and databases necessary to effectively manage the organization. In this type of distributed data environment, many organizations believe data should be managed as a strategic corporate resource, and the organization must make critical decisions concerning "...*where* to distribute *what* data, *who* should have access and at what level, and *when* and *how* to synchronize that ... data." (Bachman, 1993, p. 1/4)

This thesis examines enterprise data management at NPS in terms of its role in Information Resources Management (IRM).

B. BACKGROUND

Numerous authors address enterprise data management in terms of the information systems (IS) department's role or mission. Sprague and McNurlin (1993, pgs. 198-199) identified

four main functional areas within this IS department's data administration role: data element standards, shared data controls, distributed data controls, and data quality controls.

Data element standards are required to eliminate data redundancies and data definition inconsistencies, thus ensuring data and information compatibility throughout the organization. Establishment and use of standard data elements and data definitions in an organization-wide data dictionary is not in itself sufficient to fulfill the requirements of this functional area. Some policy implementation mechanism must be put into place to maintain the data integrity, and all the users must be trained in the proper use of data definitions.

Shared data can be defined as the data that is used by two or more organizational units within the enterprise. However, full data administration requires treating *all* data throughout the enterprise as shared data, whether or not it is used by more than one organizational unit. This type of total data control is essential to ensure that cross-departmental application programs use interoperable data, now and in the future.

Distributed data can be defined as the data that is used by organizational units which is physically dispersed, ie., situated in more than one location. The use of distributed data resources significantly complicates data administration,

and requires a greater degree of standard operating procedures and practices to ensure full data integration and interoperability.

Data quality must be maintained through the implementation and enforcement of specific policies and procedures. One favored approach is the method currently in use at NPS, which is require the owners of the data to be responsible for the data's accuracy; however, the determination of proper data ownership is a frequent stumbling block with this approach.

The data-oriented view of the mission of an IS organization is also shared by Steven Spewak and Steven Hill (1993, p. 5) who claim the IS department's mission should be "*providing quality data to those who need it*". Spewak and Hill went on to adapt Deming's 14 Points for Quality (Spewak and Hill, 1993, p. 5) and created a parallel interpretation, which they titled "*14 Points to Data Quality*". Figure I.1 presents some of these points.

Commercial sector business enterprises are not the only organizations interested in strategic data management. The Federal Government, the Department of Defense (DoD), the Department of the Navy (DoN), and even NPS also recognize the importance of data management. Chapter II provides an overview of numerous standards, rules, regulations, and guidance developed by the Federal Government, the DoD, the DoN, and NPS that are applicable to Information Resources Management (IRM) and data management at NPS.

Extract from "14 Points to Data Quality"

Develop a charter for Data Resource Management (DRM).

Manage data as an asset; commit to shared data and data integrity.

Develop measures for quality data.

Establish a data-driven migration strategy based on data creation (source data systems).

Understand your business (functional business model, business plans); correct data errors and eliminate the causes of bugs with better methodologies.

Institute DRM training programs.

Develop standards and enforcement mechanisms to ensure data quality.

Comply with standards through leadership and responsibility for data quality (provide compliance incentives).

Management must commit to these data quality principles (establish DRM, reorganize, authorize).

Figure I.1 Extract from "14 Points for Data Quality" (Spewak and Hill, 1993, p. 5)

Data management or data administration is just one part of what is commonly known as *Information Resources Management*. Many different definitions for IRM exist; Ward, Griffiths, and Whitmore (1990, p. 338) state that IRM consists of four primary activities: data administration, data dictionary administration, database administration, and provision of access services. Figure I.2 presents this view of the IRM activities, and Figure I.3 provides a listing of the tasks commonly associated with each IRM activity.

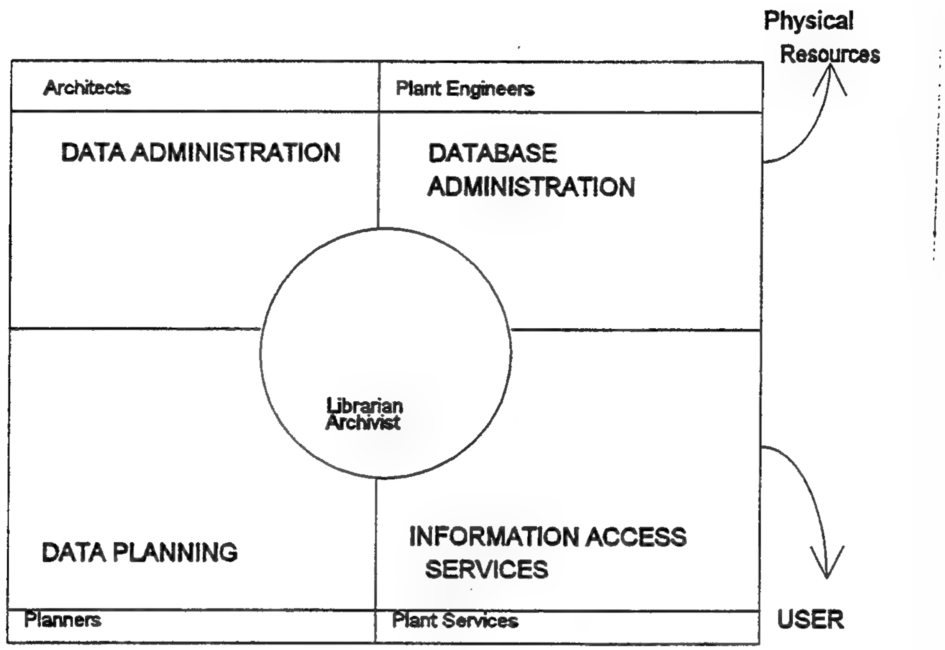

Figure I.2 Information Resources Management (IRM) Activities (Ward, Griffiths, Whitmore, 1990, p. 339)

Slight modification of the results of a Boeing Company long-range vision study (Sprague and McNurlin, 1993, p. 50) provides the architecture pyramid shown in Figure I.4.

The *business process architecture* layer defines the organization's business activities, functions, and processes.

INFORMATION RESOURCES MANAGEMENT ACTIVITY TASKS

Data Administration

1. Data planning (shown as a separate activity in Figure I.2)
2. Identification of information needs
3. Establishment of data standards and procedures
4. Management of corporate data models
5. Coordination for data-related problem resolution
6. Interface with the business
7. Establishment and implementation of activity and data analysis
8. Establishment of controls and procedures for data security and recovery, privacy, and integrity

Data Dictionary Administration

1. Authoritative source of information – the glossary and dictionary of the business
2. Evaluation and selection of data dictionary management software
3. Coordination of the data dictionary contents and meta-models
4. Establishment of standards and procedures for use of the data dictionary
5. Data definition and impact analysis

Database Administration

1. Design, development, implementation and operation of the organization's databases
2. Establishment of technical standards and procedures for database activities
3. Evaluation and selection of database management software
4. Database environment and services monitoring and control
5. Database housekeeping tasks – backups, archiving, recovery, restart
6. Policy coordination with data administration and data dictionary administration
7. Systems development planning coordination for effective database use

Information Access Services

1. Policies and procedures regarding ownership, responsibility, security, and access rights
2. Information access tools and techniques
3. User education to promote benefits of information management
4. Data quality, availability, and accessibility

Figure I.3 Information Resources Management Tasks (Ward, Griffiths, and Whitmore, 1990, p. 341-343)

James Brancheau (1989, p. 9) provides an excellent definition for the *information architecture* layer, along with a concise description of how an information architecture is used within an organization to support the business process architecture layer:

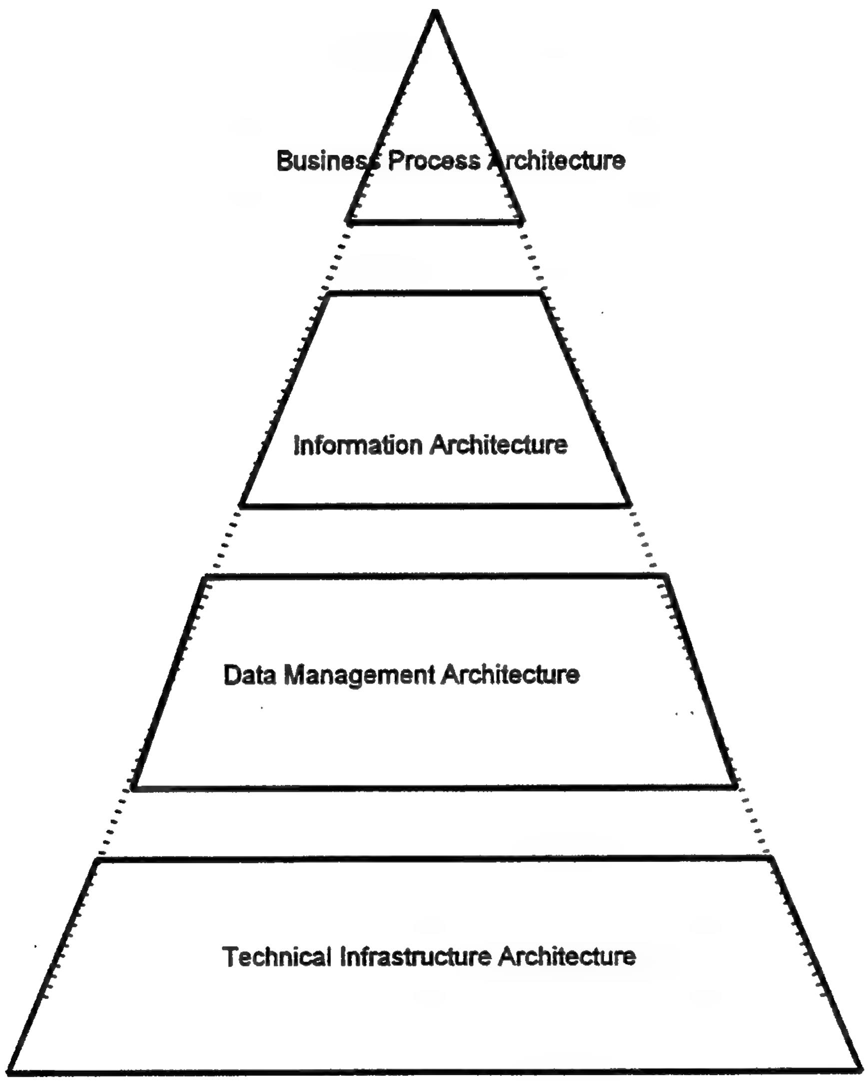

Figure I.4 Architecture Pyramid

An *information architecture* is a high-level map of the information requirements of an organization. It is a personnel, organization and technology independent profile of the major information categories used within an enterprise. It provides a way to map the information needs of an organization, relate them to specific business functions, and document their interrelationships. The interrelationships between information and functions are used to guide applications development and facilitate integration and sharing of data. An information architecture provides a proactive basis for information systems development as opposed to the reactive backlog approach common in many organizations.

A *data management architecture* layer supports the information architecture layer, and consists of all the policies, procedures, and methodologies used for data management. Finally, the *technical infrastructure architecture* layer, which underlies and supports the data architecture, consists of the organization's hardware, software, and communications networks.

This discussion of the architecture pyramid leads to the two-fold purpose of this thesis research: first, investigate the existing information architecture and data management architecture at NPS; and second, determine a recommended data management architecture to meet NPS information management requirements, subject to resource constraints.

C. RESEARCH QUESTIONS

The primary research questions to be answered by this thesis thus become:

1. What is the information architecture of the NPS enterprise?

2. What is the most appropriate data management architecture for the NPS enterprise data, considering local constraints on both financial and personnel resources?

The primary research questions will be answered by answering a set of subsidiary research questions. The subsidiary research questions are:

Information Architecture

1. What are the business activities or functions of the NPS enterprise?
2. What are the information needs of the NPS enterprise?
3. How are the information needs related to the business functions?

Data Management Architecture

4. What are the potential data management architecture alternatives for the NPS enterprise data?
5. What are the financial and personnel resource constraints?
6. What is the recommended data management alternative for the NPS enterprise data, considering all resource constraints?

D. INVESTIGATIVE METHODOLOGY

The investigative approach consists of efforts in four broad areas: collection of background information for use in the analysis of the NPS information and data management architectures; the analysis of the NPS enterprise, its information architecture, and its data management architecture; collection of information for use in the analysis of the data management architecture alternatives; and the analysis of these data management alternatives.

A brief description of each research area's investigative methodology follows:

1. NPS Information and Data Architectures Data Collection

The data collection approach consists of the identification and review of numerous organizational documents, the development and distribution of survey questionnaires to information system users, and the conduct of interviews with upper level management personnel, middle level management personnel, information system technical personnel, and information system users at multiple levels of management.

2. Analysis of NPS Enterprise and Architectures

The NPS enterprise analysis consists of performance of the tasks outlined in the Information Strategy Planning and Business Area Analysis stages of the information engineering software development methodology (Martin, 1990a). The analysis develops and discusses an NPS enterprise model using the automated support provided by a Computer-Aided Software Engineering (CASE) tool -- Texas Instruments' (TI) Information Engineering Facility™ (IEF™).

3. Data Management Architecture Alternatives Data Collection

The data collection consists of a general literature review of data management architecture alternatives, followed by specific research into the publications and vendor literature for several representative systems, applications, and products. Additional data collection efforts include

attendance at numerous industry trade shows and exhibitions, which provide opportunities to examine representative systems, applications and products, and discuss technology issues with vendor representatives. Attendance at numerous vendor-sponsored product seminars supplement trade show attendance data collection efforts, and provide more detailed information about specific technologies, technology implementation, and available commercial products.

4. Analysis of Data Management Architecture Alternatives

The data management architecture alternatives analysis consists of the application of guidance and procedures derived from the Federal Information Resources Management Regulations (FIRMR)(41 CFR 201) and other Federal Government agency publications. Subjective evaluation of each data management alternative with respect to the elements of the analysis criteria, albeit at an overview level, along with the application of financial and personnel resource constraints, allows selection and recommendation of a data management architecture alternative for implementation within the NPS enterprise.

E. SCOPE AND LIMITATIONS OF THE THESIS RESEARCH

Development of an information architecture for an entire organization is a complex and difficult task due to the broad scope of the project. Analysis of an organization as large and unique as NPS requires many more man-hours than can be

devoted to the subject within the limited timeframe allotted to a student at NPS for thesis research. Therefore, this thesis does not attempt to provide a complete and comprehensive analysis of the NPS information architecture. This research follows the outlined tasks within the first two of seven stages of the information engineering methodology (described in Chapter III) to provide a broad, high-level overview of the information architecture at NPS. The information architecture overview consists of identification and definition of the top-level business functions, identification and definition of the information subject areas and corresponding top-level data entity types, and a high-level definition of some of the relationships between the business functions and the data entity types. The overview analysis provides sufficient depth to make a preliminary assessment of the NPS organization, and provide comments and recommendations for changes to the NPS organizational structure. Chapter IV discusses several additional limitations of the analysis that occur as a result of the use of IEF™.

Proper evaluation and selection of a specific data management architecture is likewise a daunting endeavor, since the analysis must not only include the data architecture, but also the underlying technical infrastructure issues. Additionally, a true evaluation and selection process includes evaluation of vendor-specific implementations of the various

data management architectures, not just a generic data management architecture concept. This thesis does not attempt to evaluate vendor-specific implementations; the analysis only discusses the various generic alternative concepts in broad and general terms. The description of the alternative data management architecture concepts and the analysis of the NPS enterprise information architecture provide sufficient information to allow a recommendation for a data management architecture for the NPS enterprise.

F. STRUCTURE OF THE THESIS

Chapter II provides an overview of numerous standards, rules, regulations, and guidance developed by the Federal Government, the Department of Defense (DoD), the Department of the Navy (DoN), and NPS that are applicable to Information Resources Management (IRM) and data management at NPS.

Chapter III provides a description and discussion of various system analysis methodologies, including the information engineering methodology used for the NPS enterprise analysis, followed by a description of some of the features of TI's CASE tool IEF™.

Chapter IV provides a broad, high-level overview analysis of the NPS enterprise using the Information Strategy Planning (ISP) and Business Area Analysis (BAA) phases of the information engineering methodology. The results of the

analysis provide the basis for several recommendations for changes to the NPS organizational structure. The chapter also provides a brief discussion of the financial and personnel resource constraints related to IS at NPS.

Chapter V provides a general discussion of the data management architecture alternative technologies available in industry today.

Chapter VI provides a discussion and analysis of the NPS information architecture-driven requirements, and an analysis of the alternative data management architecture concepts.

Chapter VII provides a discussion of the recommended data management architecture alternative subject to all resource constraints, a summary of other recommendations as a result of the study, an evaluation of the information engineering methodology and of the TI CASE tool IEF™, and recommendations for further study.

Appendices A through F provide background information which supports the discussions in each chapter. Appendix A provides a listing of available documents which provide IRM guidance. Appendix B provides a listing of some of the Federal Information Processing Standards (FIPS) applicable to IRM. Appendix C provides a description of the IEF™ Toolsets. Appendix D provides the NPS enterprise analysis IEF™ printouts, and has a separate and limited distribution due to its bulk. Appendix E provides a discussion of middleware

technology. Appendix F provides a discussion of the FIRMR guidance for analysis of requirements and alternatives.

II. INFORMATION RESOURCES MANAGEMENT GUIDELINES

This chapter provides an overview of the standards, rules, regulations, and other policy guidance developed by the Federal Government, the Department of Defense (DoD), the Department of the Navy (DoN), and the Naval Postgraduate School (NPS) that are applicable to Information Resources Management (IRM) at NPS. The key directives at each level are examined and discussed. The emphasis in the discussion is on the management of information or data; directives addressing other IRM topics are not covered.

A. FEDERAL RULES, REGULATIONS, STANDARDS, AND GUIDANCE

The Federal Government's IRM policy guidance is distributed throughout many documents. The principal IRM policies are provided in the Federal Information Resources Management Regulations (FIRMR) and the Office of Management and Budget's (OMB) Circular A-130. Additional non-mandatory guidance and direction is available from many other Federal agencies, including the Office of Technical Assistance within the Information Resources Management Service (IRMS) of the U.S. General Services Administration (GSA). Another source of regulatory information is the Federal Information Processing Standards (FIPS). These documents are discussed in some detail in the following sections.

1. Federal Information Resources Management Regulations (FIRMR) - 41 CFR CH. 201

The FIRMR "...applies to the creation, maintenance, and use of Federal information processing (FIP) resources by Federal agencies." (41 CFR 201-1.000) Specifically, the FIRMR "...is established to publish and codify uniform policies and procedures pertaining to information resources management activities by Federal agencies." (41 CFR 201-3.101) These policies cross a wide spectrum of responsibilities, including management and use of information and records, management and use of information processing resources, and the acquisition of information processing resources. The policies are broad and general in nature, and are aimed at providing guidance at a Federal agency level. However, the policies also apply to specific organizations within each Federal agency, such as the Naval Postgraduate School. One way the FIRMR policies can be easily interpreted and applied to a specific organization is by simply replacing the word "agency" with the word "organization" throughout the FIRMR's subchapters.

The first subchapter provides general information about the FIRMR and its structure. One useful feature of this subchapter is a glossary of terms, definitions and acronyms.

The second subchapter, Subchapter B -- Management and Use of Information and Records, contains policies "...designed to promote the economic and efficient management and use of information..." (41 CFR 201-6.002). This subchapter focuses

on two major items: an overview of the importance of information management; and policies for strategic planning, records management, and use of the GSA's IRM review and evaluation programs.

The importance of managing information as a strategic organizational asset throughout its life cycle is one of the key considerations emphasized in Subchapter B. One example of a Federal agency-level policy that is equally applicable to individual organizations within the agency is the FIRMR's direction to conduct strategic planning:

> Federal agencies shall establish strategic planning processes to:
>
> Plan for the creation, collection, processing, transmission, use, storage, dissemination, and disposition of information;
>
> Ensure that program officials and information resources management officials (including records managers) participate in the development and annual revision of a 5-year plan for meeting the agency"s information technology needs; and
>
> Ensure that the agency's information needs are determined before conducting a requirements analysis for FIP resources. (41 CFR 201-7.002)

The Computer and Information Services Directorate (Code 05) at NPS coordinates the development and annual review of a five-year information technology plan which addresses these issues. The determination of the NPS organization's needs is a key part of the author's research to determine an enterprise-wide information architecture. Subchapter B of the FIRMR follows up the discussion of the planning policy with a listing of

specific factors to consider when planning future needs. These factors include: the identification of mission-essential records and information; and determination of information format, medium, quantity, integrity, and timeliness requirements.

Two more records management issues addressed in this subchapter are ensuring that an organization's records can be accessed quickly and reliably, and controlling the creation and use of forms and reports. The following extracts of specific FIRMR procedures apply not only to records management but also to information management (41 CFR 201-9.103):

> Control the creation, maintenance, and use of agency records and the collection and dissemination of information to ensure that the agency:
>
> Does not accumulate unnecessary records;
>
> Does not create forms and reports that collect information inefficiently or unnecessarily;
>
> Periodically reviews all existing forms and reports (both those originated by the agency and those responded to by the agency but originated by another agency or branch of Government) to determine if they need to be improved or cancelled;
>
> Maintains its records cost effectively and in a manner that allows them to be retrieved quickly and reliably;
>
> Additionally, each agency should strive to:
>
> Provide agency personnel with the information needed in the right place, at the right time, and in a useful format;
>
> Eliminate unnecessary reports and design necessary reports for ease of use;

> Organize agency files (i) so that needed records can be found rapidly (ii) to ensure that records are complete and (iii) to facilitate the identification and retention of permanent records and the prompt disposal of temporary records. (41 CFR 201-9.103)

Interpretation of these statements yields support for the central administration and management of an organization's data, in line with the strategic resource view of information. These statements also place an emphasis on organization-wide data integration and information system interoperability in order to more effectively and efficiently manage the information.

Subchapter C, Management and Use of Federal Information Processing (FIP) Resources, prescribes policies for the planning and budgeting, acquisition, operation, review and evaluation, and disposition of FIP resources; the subchapter also lists GSA's available services and assistance. The planning and budgeting guidance supports the policies in Subchapter B and is directed at Federal agencies at the agency level. The acquisition policies provide specific guidance for analyzing information needs, requirements, and alternatives, and addresses the use of standards. It is important to note that the acquisition section's discussion of standards only provides overall guidance to use FIPS and other standards; each standard must be individually reviewed to determine its applicability for any given requirement. The operations policies discuss the requirements to maintain FIP resource inventories, provide for security and information privacy, and

share excess FIP resources. The review and evaluation discussion provides details of two IRM programs: The Federal Information Resources Management Review Program, administered by each individual agency; and the Information Resources Procurement and Management Review Program, administered by GSA. The disposition policies provide guidance for disposing excess or obsolete FIP resources.

2. Office of Management and Budget (OMB) Circular A-130

Circular No. A-130 implements the IRM policies required by the Paperwork Reduction Act of 1980, 44 U.S.C. Chapter 35 (OMB, 1993). The Paperwork Reduction Act includes one key goal of interest with respect to information management: "Coordinate, integrate, and where practical, make uniform, Federal information policies and practices" (41 CFR 201-6.001). Circular A-130, like the FIRMR, provides policies which are broad and general in nature, and are aimed at providing guidance at a Federal agency level. However, the policies specifically apply to organizations within each Federal agency as well, due to the Circular's requirement to:

> Ensure that the information policies, principles, standards, guidelines, rules, and regulations prescribed by OMB are implemented appropriately within the agency. (OMB, 1993, p. 11)

The Circular A-130 sections most applicable to a discussion of information management are the Definitions section and the Policy section. The section on definitions is similar to the FIRMR's glossary of terms, providing definitions for the key

terms used throughout the document. The policy section is divided into two areas: Information Management Policy and Information Systems and Information Technology Management Policy.

The Information Management Policy area includes nine topics: information management planning, information collection, electronic information collection, records management, providing information to the public, information dissemination management system, avoiding improperly restrictive practices, electronic information dissemination, and safeguards. Excerpts from the planning policies identify several actions that must be carried out by agencies, and organizations within those agencies, including:

> Seek to satisfy new information needs through interagency or intergovernmental sharing of information, or through commercial sources, where appropriate, before creating or collecting new information;
>
> Integrate planning for information systems with plans for resource allocation and use, including budgeting, acquisition, and use of information technology;
>
> Train personnel in skills appropriate to management of information;
>
> Use voluntary standards and Federal Information Processing Standards where appropriate or required; (OMB, 1993, p. 6)

These directed actions are a driving force for the standardization of data to support the sharing of information. They also point out the importance of information as a strategic resource, and the emphasis that must be placed on proper information management.

One policy in the area of records management stands out: "ensure the ability to access records regardless of form or medium". (OMB, 1993, p. 7) This policy can be interpreted many ways; one interpretation provides support for the standardization of the records, and the data contained within each record.

Two of the policies discussed under the safeguards section are likewise worthy of note, since they affect the type of information which can be maintained within organizational databases:

> Limit the collection of information which identifies individuals to that which is legally authorized and necessary for the proper performance of agency functions;
>
> Limit the sharing of information that identifies individuals or contains proprietary information to that which is legally authorized, and impose appropriate conditions on use where a continuing obligation to ensure the confidentiality of the information exists; (OMB, 1993, p. 10)

These policies are further elaborated in Appendix I to the Circular, which is devoted entirely to each Federal agency's responsibilities for implementing the reporting and publication requirements of the Privacy Act of 1974, 5 U.S.C. 552a, as amended (OMB, 1993, p. 17).

The Information Systems and Information Technology Management Policy area prescribes 18 specific agency requirements related to an information system's life cycle (OMB, 1985, p. 52736). Some of these actions include:

1. a requirement for multi-year strategic planning;
2. periodic review of system requirements over the system lifecycle for applicability;
3. non-duplication of information systems available from other agencies;
4. use of commercial-off-the-shelf (COTS) software when cost effective; and
5. use of FIPS and other standards unless costs exceed benefits or use prevents mission accomplishment.

These requirements do not provide additional guidance; they simply support the policies addressed in earlier sections of the document.

The remaining sections of the OMB Circular provide guidance in other areas related to information system management. Appendix II to Circular A-130 provides guidance on cost accounting issues and interagency sharing of IS facilities. Appendix III addresses security issues relating to Federal automated information systems. Appendix IV provides an analysis of the key sections of the Circular to provide some explanations for the Circular's content. (OMB, 1985, p. 52741-52744)

3. GSA Information Resource Management Service (IRMS) Publications

The IRMS's Office of Technical Assistance (OTA) disseminates a wealth of useful information through the publication of numerous information technology documents. The IRMS-OTA documents do not constitute official Federal Government or GSA policy or regulation; they only provide

ideas and information, and can serve as useful references for IS managers. Some of these documents are available free of charge to Government agencies; others can be purchased for a nominal fee from the National Technical Information Service (NTIS) of the Department of Commerce.

Similarly, the IRMS's Federal Systems Integration and Management Center (FEDSIM) routinely publishes documents which shares the information gained by FEDSIM in its work with other Federal agencies. These publications are also offered free of charge to Government organizations. One example of this type of document is the *Information Resources Management Strategic Planning Guide* (FEDSIM, 1993), which provides a guideline for compliance with the FIRMR's and OMB Circular A-130's requirements to conduct strategic IRM planning within Federal agencies.

A listing (titles and description) of some of the documents available from the IRMS is included in Appendix A.

4. Federal Information Processing Standards (FIPS)

FIPS are individual standards related to automated data processing, and are categorized in one of five areas: hardware, software, application, data, and operations. Each category also has sub-categories, and some FIPS fall within more than one category, such as FIPS dealing with network protocols. The first FIPS were issued in the late 1960s by the U.S. Department of Commerce's National Bureau of

Standards, now known as the National Institute of Standards and Technology (NIST). The majority of the technical FIPS adopt American National Standards (ANS) for automated data processing developed by the American National Standards Institute's (ANSI) X3 Committee (Computers and Information Processing). Some adopt International Standards approved by the International Standards Organization (ISO), or joint ISO/ANSI standards. Many FIPS are simply non-mandatory guidelines written to serve as technical references for IS personnel in some area of information processing. Some of these standards have been adopted and implemented commercially as well. The Federal Standards are periodically reviewed, and the FIPS are revised or superseded if required whenever the underlying ISO or ANSI standards are updated.

The FIPS are too numerous to attempt to list and describe in their entirety. Even listing just the FIPS that can be considered applicable to information processing or information management at NPS would be excessive; therefore, a small representative sampling of the applicable FIPS in each category is provided in Appendix B.[1]

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[1]NIST publishes a handbook, updated annually, which provides an index and description of all the Federal Standards.

B. DEPARTMENT OF DEFENSE (DoD) RULES, REGULATIONS, STANDARDS, AND GUIDANCE

DoD guidance tends to fall into one of three categories: implementation of higher-level guidance, such as the FIRMR and OMB Circular A-130, with DoD specific supplementation; specific DoD IS acquisition and life-cycle management guidance; and the Corporate Information Management (CIM) Initiatives. The implementation of higher-level guidance is generally provided as policy in DoD Directives, supported by procedures in DoD Instructions. The DoD IS acquisition policies and procedures are likewise promulgated through specific DoD Directives and Instructions. Many of the directives associated with information management are recent revisions brought about by the implementation of the CIM Initiative; other directives are still under revision.

1. The Corporate Information Management (CIM) Initiatives

The Goldwater-Nichols Act of 1979 directed government organizations to streamline their organizational structures. As new information processing technologies became available, DoD's focus shifted to information management, resulting in the CIM Initiatives. The CIM Initiatives mandated that organizations must, prior to automating any process, scrutinize their work processes, delete unnecessary processes, and eliminate redundancy; in other words, organizations must conduct business process engineering. The key focus of the DoD directives produced as a result of the CIM Initiatives is

the integration of common business functions across organizational lines. (ODDI, 1993)

The *Corporate Information Management For the 21st Century - a DoD Strategic Plan* (ASD-C3I, 1994) contains the current top-level guidance for all information management activities within the DoD. The plan includes goals in the following six areas: functional process reengineering, the standardization and sharing of data, the migration of information systems, a computer and communications infrastructure, and management of the Corporate Information Management (CIM) initiative throughout DoD. The goal related to standardization and sharing of data is the most relevant to the research for this thesis. The specific objectives for this goal (ASD-C3I, 1994, p. 9) are:

> Derive standard definitions of data, on an aggressive schedule.
>
> Establish strong management of data quality, including data availability, integrity, accuracy, and security.

The DoD plan to meet these objectives (ASD-C3I, 1994, p. 9) includes:

1. Establish policies and programs to ensure that requirements for end-to-end data availability, integrity/quality, and security are met.
2. Establish programs to ensure compliance with data policies and programs.
3. Develop standard definitions of data through the application of a DoD data model and functional data models, utilizing a central data dictionary.

4. Aggressively pursue opportunities to share data and establish shared data bases within the DoD, with other government agencies, and with allies.

5. Coordinate and integrate DoD-wide data standardization initiatives supporting cross functional applications including CALS [Continuous Acquisition and Life-Cycle Support], EC/EDI [Electronic Commerce/Electronic Data Interchange], and Modeling & Simulation. This should include application of the Integrated Data Environment (IDE) concept and technologies.

6. Reduce costs while ensuring the effectiveness of data/information through efficient data capture, collection, processing, storage, and dissemination.

7. Implement a Data Administration Program which includes procedures for standardizing data, promulgating and enforcing use of standard data elements, and oversight reviews of Service/Agency programs.

Some of these actions, such as develop standard definitions for data, are already underway throughout DoD. Other actions remain to be implemented, with the guidance expected in the follow-on *Corporate Information Management Operational Plan* (ASD-C3I, 1994).

The CIM Strategic Plan is accompanied by the *Enterprise Integration Implementing Strategy* (DISA-CFI&I, 1994), which provides a description of the approach and initiatives required to accomplish the plan's goals. The proposed frameworks for achieving Enterprise Integration (EI) are the DoD Enterprise Model and the Technical Architecture Framework for Information Management (TAFIM).

The DoD Enterprise Model is a high-level model of the DoD as an enterprise, and consists of a data model and a function model. The concept of an Enterprise Model provides

the means for describing how each organization will fit into the DoD Enterprise (DISA-CFI&I, 1994, p. 24). Each functional organization is expected to reengineer their processes to conform with the DoD Enterprise Model, allowing integration into the overall DoD-wide structure. Figure II.1 shows the top level of the DoD Enterprise Data Model, and Figure II.2 shows the top level of the DoD Enterprise Activity Model.

The TAFIM does not define a specific system architecture; it provides the components -- services, standards, design concepts, equipment, and configurations -- that will guide the development of technical architectures within DoD. The TAFIM is independent of mission-specific applications and data types, and therefore promotes interoperability, portability, and scalability. Since all DoD information systems must be interoperable at some time in the future, the use of the TAFIM now will allow development of systems that will more easily reach interoperability in the future. (DISA-CFA, 1993, p. 3)

The TAFIM does not only address technical architectures. The data architecture and the application software architecture must be integrated with the technical architecture to create a complete information system. Accordingly, the TAFIM provides some discussion of each of these architectures as they relate to the technical architecture, and their integration through the use of the hierarchical DoD Information Management (IM) Integration

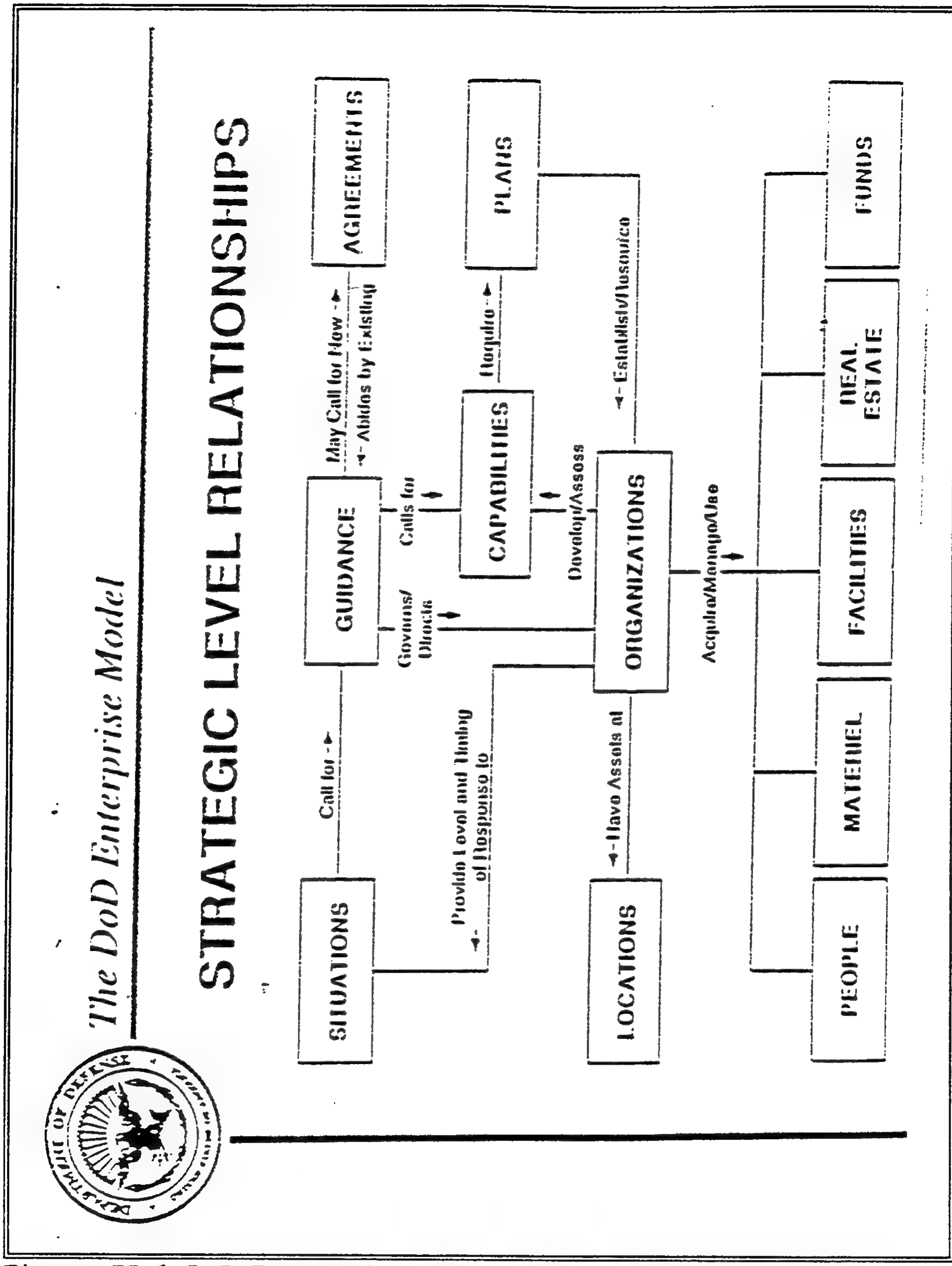

Figure II.1 DoD Enterprise Data Model - Strategic Level (DDI, 1993)

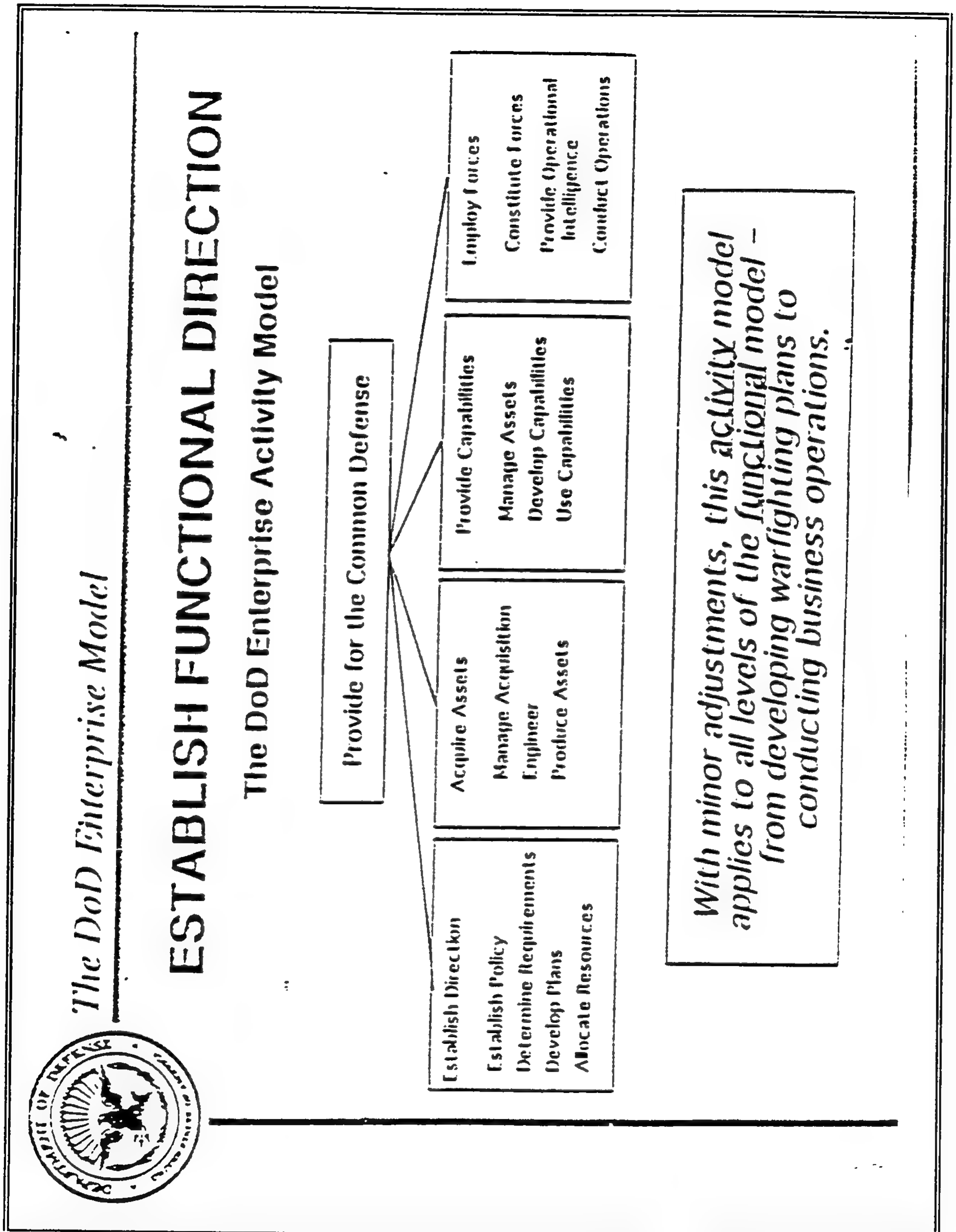

Figure II.2 DoD Enterprise Activity Model - Strategic Level (DDI, 1993)

Model. Figure II.3 provides a view of the IM model. The CIM program has expanded the IM model to add two levels, and renamed it as the CIM Integration Architecture. Figure II.4 provides a view of this new version. The TAFIM also provides a vision for DoD Information Management (DISA-CFA, 1993, p. 61), which correlates well with the goals of the *Corporate Information Management Strategic Plan*.

2. DoD Directives and Instructions

The DoD Directives and Instructions which are most applicable to information and data management are:

Compatibility, Interoperability, and Integration of Command, Control, Communications, and Intelligence (C3I) Systems (DoD Directive 4630.5, 12 November 1992) provides the overall directive for functional and technical integration of DoD system requirements to achieve system interoperability.

Procedures for Compatibility, Interoperability, and Integration of Command, Control, Communications, and Intelligence (DoD Instruction 4630.8, 18 November 1992) provides the specific implementation guidance for accomplishing the requirements of the related DoD Directive.

Defense Information Management (IM) Program (DoD Directive 8000.1, 27 October 1992) establishes the DoD policies for the implementation, execution and oversight of DoD IM Program. All of the policies listed within this

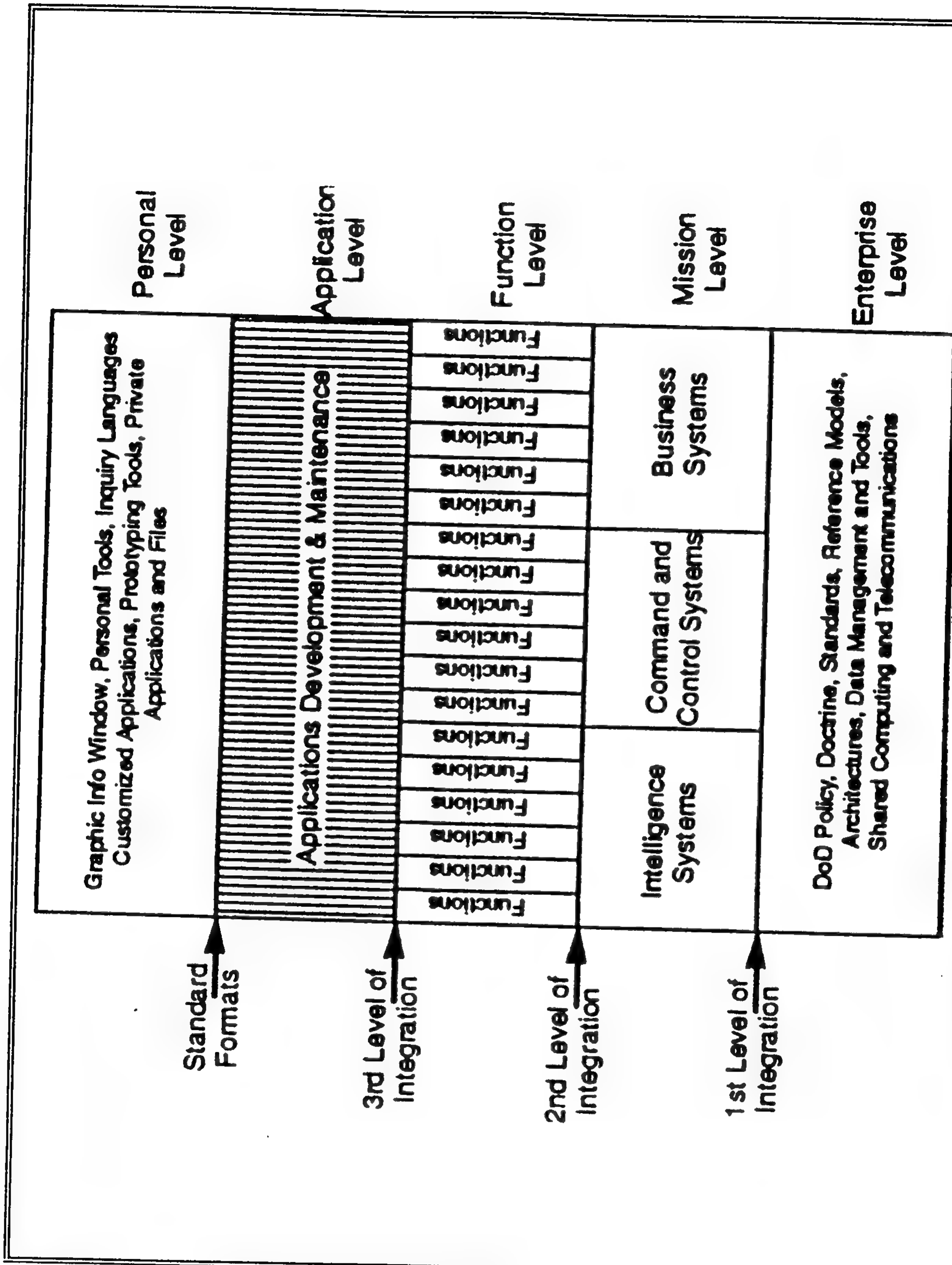

Figure II.3 IM Integration Model
(TAFIM, Vol.1, 1993, p. 28)

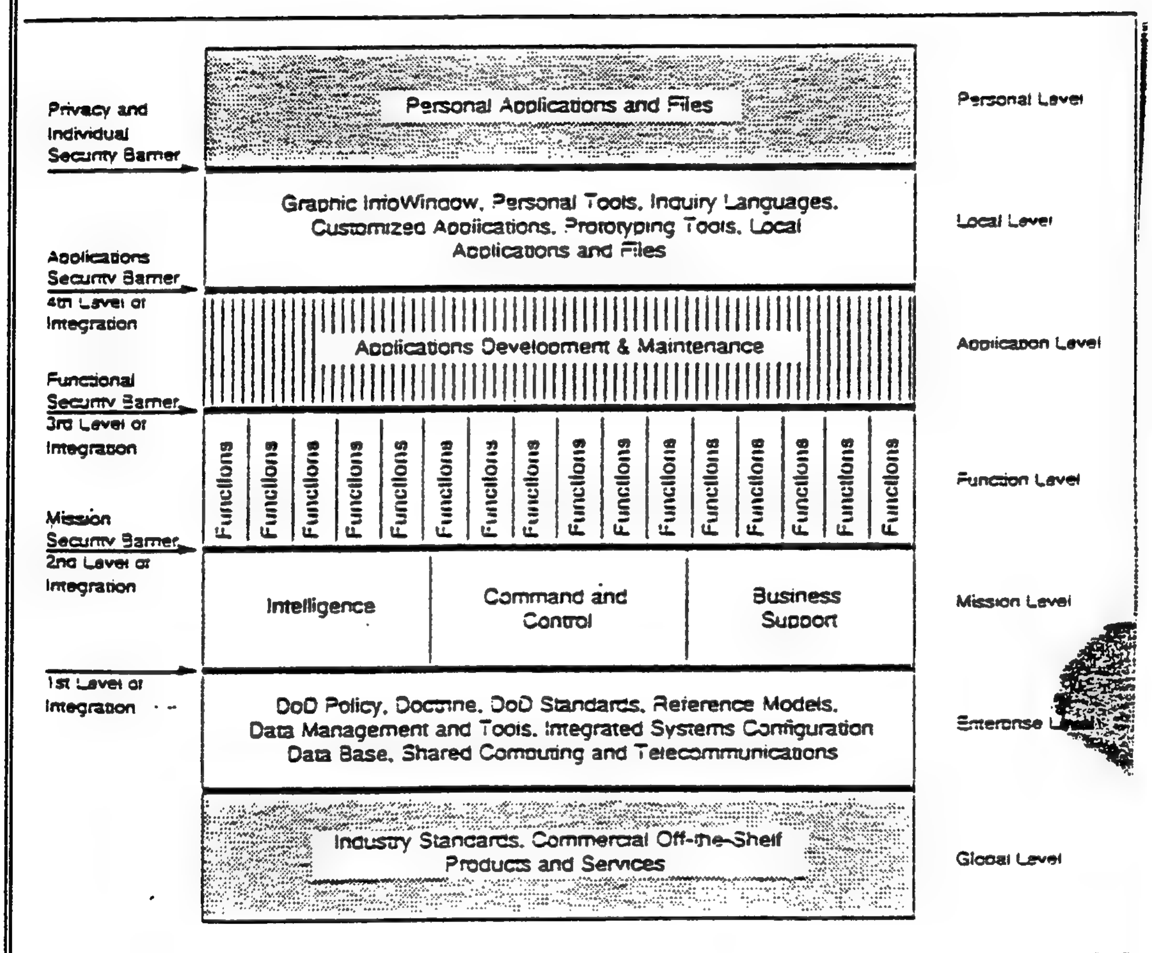

Figure II.4 CIM Integration Architecture
(D. Appleton, 1993, p. 23)

directive apply to NPS. Some of the policies specifically address information and data management:

1. Data and information are corporate assets. The information must be structured to allow full interoperability and integration throughout DoD.

2. Functional process re-engineering should be based on DoD-approved activity models and data models.

3. The entire information system lifecycle should be managed from a DoD-wide perspective to ensure cross-functional consistency of information.

4. Approved DoD-wide methods, approaches, models, tools, data, and information technology should be used wherever possible.

5. Standard DoD data definitions must be used for all information systems.

The DoD policy to treat information as a corporate asset is simply a reiteration of higher-level guidance. The requirement to use a structure to allow DoD-wide integration and interoperability leads directly to data element standardization, which is specifically addressed. The DoD-approved activity models and data models are encompassed within the DoD Enterprise Model. The approved DoD methods for working with the activity models and data models are the IDEF0 and IDEF1X modeling techniques. These modeling techniques and their specific modeling languages are the result of the U.S. Air Force's Integrated Computer Aided Manufacturing (ICAM) program, and derive their name from that program -- **I**CAM **Def**inition Languages. Activity modeling uses IDEF0, with the

Activity Modeling Language (AML); data modeling uses IDEF1X, with the Structural Modeling Language (SML).[2] (D. Appleton, 1993, p. 158)

This directive also includes a listing of the principles to be used to guide the implementation of the DoD IM Program. Three key principles are:

1. Information systems must be developed using process models that are based on business methods.

2. Data definitions must be standardized DoD-wide.

3. Data entry must only happen once.

The first principle endorses the use of top-down business planning analysis methodologies, such as information engineering. The second principle is simply a reiteration of other policy statements. The third principle addresses the issue of data redundancy within organizational information systems that are not integrated or interoperable, thus preventing single data entry processing.

DoD DATA ADMINISTRATION (DoD Directive 8320.1, 26 September 1991) provides the policies for data administration throughout DoD, authorizes the promulgation of data element standardization procedures, and establishes a DoD Information Resource Dictionary System (DoD IRDS). This directive is one of the first documents revised as a result of the CIM

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[2] The IDEF0 and IDEF1X modeling techniques are discussed in greater detail in Chapter III.

Initiatives. This directive has two sections of importance -- the Concept section and the Policy section.

Seven concepts are described in the concept section: four concepts address the importance of data administration within DoD, two concepts address the tools of data administration, and one concept discusses data element standardization. One of the key concepts involves the description of the DoD data administration tools:

> The primary tools of data administration are an IRDS and a functional data structure and rules. That structure and the rules establish a framework within which to determine what data elements should be standardized, describe how data elements should be grouped, and state which data elements should be located in the DoD IRDS. The functional data structure is determined by the data needs of the organization. The DoD IRDS is used to define, structure, and maintain metadata for data administration. (DoD, 1991, p. 3)

Although the functional data structure is defined by the organization at the local level; the rules are promulgated by DoD in DoD Directive 8320.1-M-1 (See below). A detailed description of the DoD IRDS and the related procedures for its use are also provided in DoD Directive 8320.1-M-1.

The directive's concepts must be considered when implementing the directive's policies since the policies are only described using general terms. Three of the policies which provide top-level data management guidance are:

> Implement data administration aggressively in ways that provide clear, concise, consistent, unambiguous, and easily accessible data DoD-wide, and that minimize the cost and time required to transform, translate, or research differently described, but otherwise identical, data.

> Standardize and register data elements to meet the requirements for data sharing and interoperability among ISs throughout the Department of Defense.
>
> Use applicable Federal, national, and international standards before creating DoD standards or using common commercial practices.

These policies provide unequivocal high-level guidance for the use of standards in data administration.

The *DoD DATA ADMINISTRATION* directive has an accompanying document, *DATA ELEMENT STANDARDIZATION PROCEDURES* (DoD Directive 8320.1-M-1, January 1993), which provides the specific procedures for developing, approving and maintaining DoD standard data elements. This directive is the only document that specifies the actual conditions for applying the DoD guidance and policy with respect to DoD-wide data standardization. The specific conditions that apply to any organization, not just NPS, are:

1. The procedures are mandatory for use after January 1993 for all new information system development, information system modernization that affects 30% or more of the existing lines of software code, or the addition of any new data elements to a system.

2. Data elements in existing systems do not need to be restructured to conform to DoD standards unless the information system is designated as a DoD migration system.

There are some exceptions to these requirements, but they deal with special cases that generally do not apply to NPS systems. As a result of these conditions, most of the NPS information systems and their data are currently exempt from meeting the DoD data element standards. However, the other DoD policy

directives foreshadow a future migration of all DoD data to DoD-wide standard data elements to enable better functional integration and interoperability.

C. DEPARTMENT OF THE NAVY (DoN) RULES, REGULATIONS, STANDARDS, AND GUIDANCE

The DoN guidance, like the DoD-level guidance, implements higher-level guidance and provides specific supplemental direction when required. The DoN guidance is contained in Secretary of the Navy (SECNAV) Instructions (SECNAVINST) and Navy Instructions (OPNAVINST).

1. Secretary of the Navy (SECNAV) Instructions

INFORMATION RESOURCES (IR) PLANNING (SECNAVINST 5230.9A, 16 October 1985) provides the DoN guidance for conducting long-range strategic information resources planning to support mission accomplishment. This instruction specifically implements the guidance found in higher directives, including the Federal Government level guidance in OMB Circular A-130. One of the key components in this document is the requirement for each individual DoN component, such as NPS, to submit a Component Information Management Plan (CIMP) and update the CIMP annually. The CIMP is a standard format document which addresses the following planning areas: IRM organization, mission requirements, IS architecture, IRM objectives, IS resource acquisitions, and resource requirements. Information Requirements Plans (IRP) provide

more detailed discussion of the individual information requirements, divided into functional areas.

The other key SECNAV Instruction is *Life Cycle Management Policy and Approval Requirements for Information Systems Projects* (SECNAVINST 5231.1C, 10 July 1992), which also addresses a requirement for components to submit CIMPs as part of the IS life cycle management process.

2. Navy Instructions (OPNAVINST)

There are no specific OPNAV Instructions that address strictly information management or data management; the areas addressed by OPNAV Instructions are Automated Data Processing (ADP) security, and inventory controls. However, the Chief of Naval Operations (CNO) has promulgated new guidance (CNO, 1994) for submitting the CIMP based on three drivers: full Navy participation in the DoD CIM program, integration of active and reserve IS, and use of client-server and other technologies to enhance productivity.

3. Naval Postgraduate School Guidance

NPS has two instructions related to information resources management: one instruction addresses acquisition of information resources and implements higher-level guidance on life-cycle management; the other instruction addresses ADP security.

However, there are other potential sources of guidance. The NPS Computer Advisory Board's (CAB) draft *Naval*

Postgraduate School Information Systems Vision Statement (hereafter NPS-IS Vision) (NPS-CAB, 1993) describes a vision for computing and information technology, and includes a strategy, and initial implementation goals. The proposed vision statement includes an integrated approach to computing and information resources management, which follows the current DoD guidance. The proposed vision statement also includes a centrally managed computer architecture using "fully-distributed systems, which are interconnected to maximize shared utilization of campus resources" (NPS-CAB, 1993). One of the key proposed strategies is the administrative strategy. This proposed strategy implements the vision of a fully integrated system, incorporating centralized strategic planning and decentralized data administration.

The draft *Principles for NPS Information Resource Management* (NPS-IS, 1993) are modeled directly after DoD's *Principles of Information Management*, found in DoD Directive 8000.1(D). Several of these proposed principles are key to the future of data management at NPS:

1. NPS users are accountable for the accuracy of the data in their information systems. Each information system is under the stewardship of a functional manager.
2. NPS and Navy data standards are invoked.
3. Data will be entered only once.
4. All data maintained by any organizational unit is considered part of the corporate NPS data, and will be accessible to any authorized users.

These proposed principles require functional managers to be responsible for data management within their systems, following the approved data standards, and correspond to the draft NPS-IS Vision's espoused strategy of decentralized maintenance of data elements.

D. CHAPTER SUMMARY

The preceding overview of the IRM guidance provided at all levels of NPS's chain-of-command, up through the military and Federal Government hierarchy, reinforces the importance of proper information and data management. It also demonstrates the renewed emphasis on the use of standards, especially data element standards, as a mechanism to achieve enterprise-wide integration and interoperability.

The next chapter builds on some of this guidance in the discussion of the methodology and approaches chosen for this research project.

III. RESEARCH METHODOLOGY AND AUTOMATED TOOLS

This chapter provides a brief discussion of the system development methodology alternatives, the methodology selected (information engineering), and the automated tools used.

A. SYSTEM DEVELOPMENT METHODOLOGIES

A study on data management practices by Dale Goodhue, Judith Quillard, and John Rockart (Sprague and McNurlin, 1993, p. 200) points out three traditional approaches to enterprise-wide data management: technical, organizational, or business. The technical approach uses database management systems (DBMS), data dictionaries, and data entity-relationship (E-R) modeling. The organizational approach creates data and database administrator positions and formal administrative policies and procedures for data management. The business approach uses top-down, business planning processes which tie data requirements to business objectives. Examples of business approaches are Enterprise Architecture Planning (EAP), Information Engineering, Business Systems Planning (BSP), and other strategic systems planning methodologies. Studies by C.J. Coulson (1982), B.K. Kahn (1983), and G.D. Tilman (1987) show that the technical and organizational approaches are inadequate; therefore the business approaches draw more attention today.

A top-down business approach involves top-management in the planning process and focuses first on the organization's overall goals and strategies.

> The logic here is that above all, information systems need to be responsible to and supportive of an organization's basic goals. These goals should be the driving force behind the development of all information systems. (Senn, 1990, p. 654)

The use of a top-down approach creates an overall framework for developing any computerized enterprise. Systems developed separately still fit into this framework. The enterprise-wide (top-down) approach makes it possible to achieve coordination among these separately built systems, and facilitates the long-term evolution of systems. The same data is represented in the same way in different systems, resulting in integration among systems where needed. All the business approach methodologies use a top-down approach; they differ only in the implementation details and level of integration.

1. Enterprise Architecture Planning (EAP)

Enterprise Architecture Planning (EAP) is Steven H. Spewak's process "for defining the top two layers of the Zachman Information Systems Architecture Framework". (Spewak, 1993, p. xxi) The Zachman Framework identifies an information systems architecture framework consisting of three kinds of architectures -- data, process (application), and network (technology). The three architectures span six levels, or phases; these levels are explained using an analogy to the

process of planning, drafting, and building a new home. The six levels are: objectives/scope (ballpark view), model of the business (owner's view), model of the information system (designer's view), technology model (builder's view), detailed representations (out-of-context view), and functioning system. (Spewak, 1993, p. 11-12)

Since EAP only deals with the top two layers of the Zachman Framework, EAP only provides a high-level blueprint of the data, applications, and technology. EAP is a business-driven or data-driven model because a stable business model (independent of organizational boundaries, systems, and procedures) is the foundation for the architectures; the data is defined first; and data dependency determines the sequence for implementing application systems. (Spewak, 1993, p. xxi)

2. Business System Planning (BSP)

Business Systems Planning (BSP) is one of the most widely used methods for information systems planning. Originally developed by IBM as an internal tool, BSP is now a publicly available generalized planning methodology; IBM even prepares manuals and training courses to assist firms in the proper use. BSP treats all data as a corporate resource which requires the investment of time and financial resources, and a commitment of management and staff, to capture, store, and preserve the data. BSP uses a top-down approach to define the data necessary to run an organization. (Senn, 1990, p. 661)

BSP has three major limitations. First, BSP only focuses on existing organizational system details, with little emphasis on requirements for improving systems. "... BSP describes what *is*, not *what is important*." (Senn, 1990, p. 662) Second, BSP is very effective in identifying current information systems requirements. However, BSP does not provide an automated method for incorporating long-range needs into the analysis results. Finally, completion of a BSP study requires an inordinate amount of time. The analysts must interview a sizable number of managers in order to develop a broad and comprehensive understanding of the organization's requirements. Next, the analysts must synthesize the data, which is a challenging task. (Senn, 1990, p. 662)

3. IDEF0 and IDEF1X

The U.S. Air Force has a program for Integrated Computer Aided Manufacturing (ICAM), which developed a series of modeling techniques during the 1970s. The Air Force uses these modeling techniques, known as the IDEF (ICAM Definition) techniques, to produce "function models" (IDEF0), "information (data) models" (IDEF1), and "dynamics models" (IDEF2). A function model is a structured representation of the functions, activities or processes within the modeled system or subject area. An information model represents the structure and semantics of information within the modeled system or subject area. A dynamics model represents the time-

varying behavioral characteristics of the modeled system or subject area. As a result of another U.S. Air Force program, the Integrated Information Support System (I^2S^2), IDEF1 is now IDEF1X, an enhanced version of IDEF1. Both IDEF0 and IDEF1X are now Federal Information Processing Standards (FIPS)[3] as a result of their adoption by the Department of Defense for use with the Corporate Information Management (CIM) initiatives. (NIST, 1993a, p. i)

IDEF0 (Integration DEFinition language 0), based on Douglas T. Ross' and SofTech, Inc.'s SADT™ (Structured Analysis and Design Technique™), includes both a definition of a graphical modeling language (syntax and semantics) and a description of a comprehensive methodology for developing models. IDEF0 produces a model that consists of a hierarchical series of cross-referenced diagrams, text, and a glossary. The two primary modeling components are the functions and the data (objects) that inter-relate those functions. The IDEF0 methodology also includes procedures and techniques for developing and interpreting many different kinds of models, including models for data gathering, diagram construction, review cycles, and documentation.
(NIST, 1993a, p. ii)

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[3]The IDEF0 modeling technique is promulgated as FIPS 183. The IDEF1X modeling technique is promulgated as FIPS 184. Copies of the FIPS are available for sale from the National technical Information Service, U. S. Department of Commerce.

IDEF1X is a semantic data modeling technique, based on relational theory and entity-relationship models, which uses a "conceptual schema" to provide a single integrated definition of the data within an enterprise. The conceptual schema definition is independent of how the data is physically stored or accessed. The primary objective of the conceptual schema is data integration through a consistent definition of the meanings and interrelationship of data. The primary components of IDEF1X are data entities, data entity attributes, and the relationships between data entities. (NIST, 1993b, p. iii)

The most significant limitation of the IDEF techniques is the lack of integration between the methodologies. Although each technique -- information (data), function, and dynamics -- provides integration within its methodology, there is no integration of the models developed by each technique.

4. Information Engineering

Information engineering is a structured methodology that is recognized as one of the leading enterprise wide data analysis methodologies. Enterprise modeling requires an effective methodology. An effective enterprise modeling methodology uses one technique that consistently states the enterprise's goals, purpose, context, strategy, markets, threats and opportunities, critical success factors, controls, policies, procedures, and business rules. To be effective,

the technique allows users at every level to view the organization from their perspective at any time. The views are integrated to allow mapping of functions, information states, organization, resources, control, and security. Other requirements for enterprise modeling include effectively recording the state and impact of the external environment; being able to integrate enterprises physically distributed; and being able to incorporate technology-independent logical modeling. Information engineering incorporates this concept of enterprise modeling which differentiates it from conventional methodologies. (Clark, 1992, p. 31)

The information engineering methodology has three main variants: the classical information engineering approach, the business system implementation approach, and the rapid application development (RAD) approach. The classical approach includes seven stages: Information Strategy Planning (ISP), Business Area Analysis (BAA), Business System Design (BSD), Technical Design (TD), Construction, Transition, and Production. The business system approach is similar to the classical approach, except that the Business System Design, Technical Design, and Construction phases are treated as simply one stage. The rapid development approach is significantly different due to changes in the duration and cutoff points of each stage and an emphasis on group development techniques. RAD stages are: Information needs

Structuring (INS), Requirements Planning (RP), User Analysis and Design (UD), Construction, and Cutover.

The individual techniques and methods used by the information engineering methodology include: flow charting, functional decomposition, modular programming, structured programming, structured design, structured analysis, strategic data planning, data modeling, and object-oriented analysis and design. While many of the individual techniques used in the information engineering methodology originated elsewhere, information engineering clearly defines how the deliverables from one technique relate to the deliverables from other techniques within and across development phases. Thus the information engineering methodology provides the integration of the data, activities, and interactions missing in the other approaches.

The information engineering methodology provides the basis for many automated tools. One of the best known is Texas Instruments' (TI) Computer Aided Software Engineering (CASE) tool Information Engineering Facility™ (IEF™), which implements the classic information engineering methodology approach. IEF™ does not have a capability to directly integrate IDEF0 and IDEF1X models. However, a companion tool, TI's Business Design Facility™ (BDF™), can create or import IDEF0 and IDEF1X models and port them directly to IEF™.

The integration capabilities of the information engineering methodology, coupled with the ready availability

of automated support, provide significant incentive for selecting information engineering as the methodology of choice.

B. INFORMATION ENGINEERING METHODOLOGY

James Martin and Clive Finkelstein first introduce the information engineering methodology in the early 1970s as a data-driven strategic information systems (IS) development methodology supporting the entire IS lifecycle (Zeiders, 1990, p. 4).[4] The information engineering methodology has seen multiple refinements since its introduction, and is now a comprehensive system development methodology which involves the application of formal structured techniques to an enterprise as a whole in order to maximize the value of information systems in use throughout the enterprise (Martin, Book II, 1990, p. 1). The methodology supports information systems integration through the use of a common repository of data models, process models, and other design information. The common repository facilitates the identification of common data entities and common rules, thus supporting reusable designs and reusable code (Martin, Book II, 1990, p. 1).

Martin describes information engineering as a two-sided pyramid with four basic levels: *strategy* (Information Strategy

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[4] Clive Finkelstein provides a concise chronology of the evolution of Information Engineering in his book *An Introduction to Information Engineering* (Finkelstein, 1989, Ch.2).

Planning), *analysis* (Business Area Analysis), *design* (System Design), and *construction*. One side of the pyramid relates to data, and the other side of the pyramid relates to activities, or processes. Figure III.1 provides an illustration.

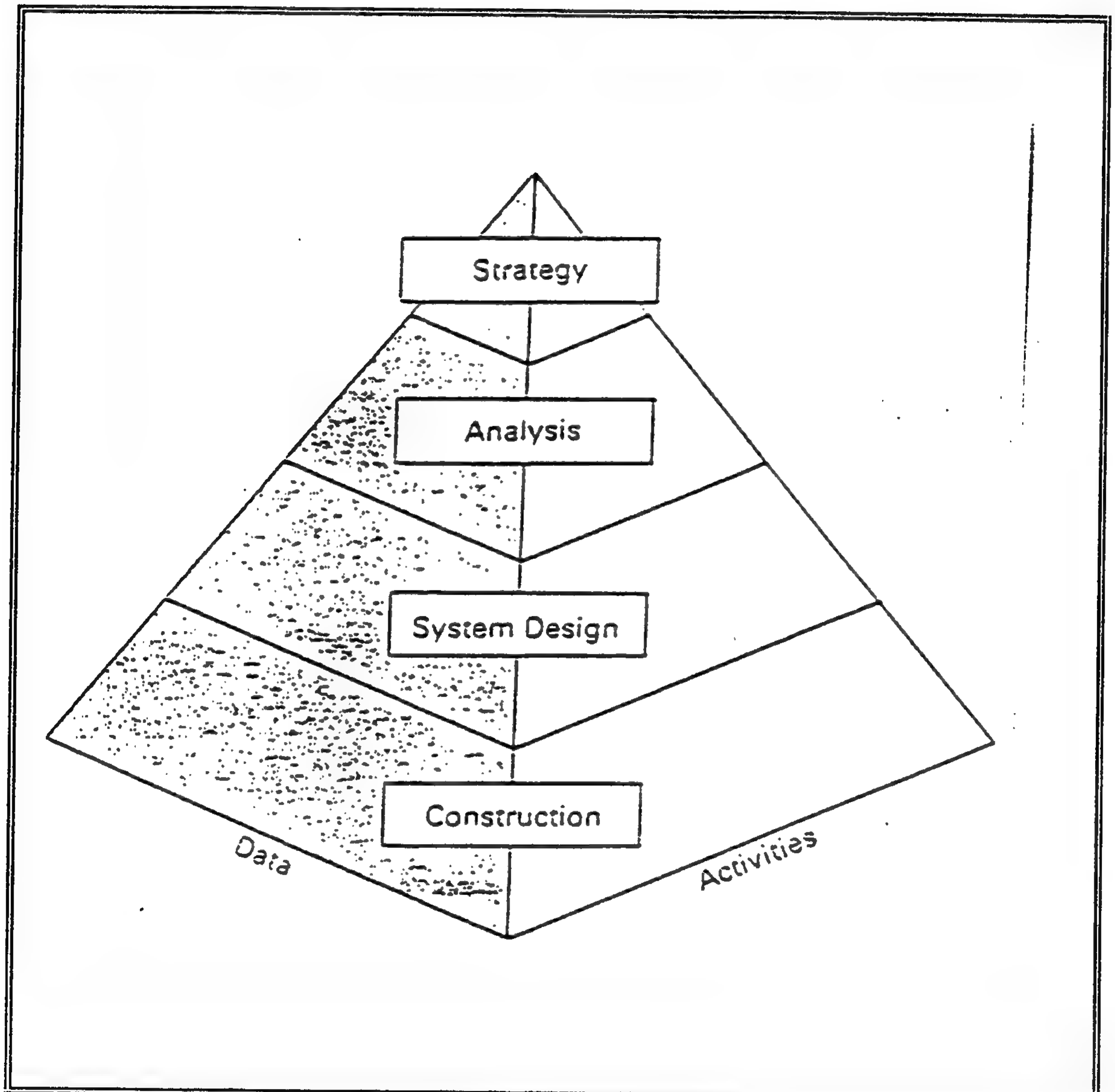

Figure III.1 Information Systems Pyramid
(Martin, Book I, 1989, p. 4)

The four levels of the pyramid represent the four stages or phases of information engineering implementation, and are discussed in greater detail below:

1. Information Strategy Planning (ISP)

> Concerned with top management goals and critical success factors. Concerned with how technology can be used to create new opportunities or competitive advantages. A high level overview is created of the enterprise, its functions, data, and information needs. (Martin, Book I, 1989, p. 13)

> The information strategy plan maps the basic functions of the enterprise and produces a high-level model of the enterprise, its departments, its functions, and its data. (Martin, Book I, 1989, p. 102)

The Information Strategy Planning phase further subdivides into two areas -- Strategic Information Planning and Enterprise Modeling. Each of these areas is itself made up of several key components (Martin, Book II, 1990, p. 13):

a. Strategic Information Planning

Strategic Information Planning contains the planning issues which most directly concern top management.

(1) Analysis of Goals and Problems. During this analysis phase, a structured model of the enterprise's strategy, mission, objectives, goals, and problems and their association with specific organizational units, information needs, and information systems is created.

(2) Critical Success Factor Analysis. During this analysis phase, those areas of the enterprise which must operate properly to achieve enterprise success are identified.

The analysis includes identification of the critical assumptions, the critical information needs, and the critical decisions requiring IS support.

(3) Technology Impact Analysis. During this analysis phase, the business opportunities and threats provided by the continuing evolution of technology are identified and prioritized.

(4) Strategic System Vision. During this phase, methods for making the organization more competitive through the strategic use of information systems and information systems technology are examined. Charles Wiseman has classified these methods as strategic thrusts, dividing them into five categories: Differentiation, Cost, Innovation, Growth, and Alliance. Additionally, each category can have offensive or defensive modes (Martin, Book II, 1990, p. 134).

b. Enterprise Modeling

Enterprise Modeling contains the planning issues which most directly concern the top level information system planners.

(1) Overview Model. First, a hierarchical map of the business functions and their associations with organizational units, the physical location, and the data entities is created. This generally consists of a set of computerized matrices.

(2) Entity-Relationship (E-R) Modeling. A diagram or chart of the data entities and their associations or relationships with each other, and with the business functions, is created. Clustering analysis of the data entity/business function relationships is also performed.

2. Business Area Analysis (BAA)

> Concerned with *what* processes are needed to run a selected business area, *how* these processes interrelate, and *what* data is needed. (Martin, Book I, 1989, p. 13)

During the Business Area Analysis phase, the models created during the Information Strategy Planning stage are refined in greater detail. The analysis is conducted through the development of two types of model sets -- data models, and process (or function) models:

a. Data Modeling

The Data Entity-Relationship Diagrams created during the Information Strategy Planning stage are refined by concentrating on a single business area at a time. Each business area can be either a pre-defined grouping of business functions and data, or a clustering of functions and data determined during the Information Strategy Planning stage. The refined E-R diagrams then become the data model, and are fully normalized at this stage. An analysis of the interrelationships between the data and the processes, describing which processes create, read, update, or delete data, is also conducted, through the use of matrices.

b. Process Modeling

The process modeling consists primarily of a Process Decomposition Diagram, which provides a detailed hierarchical view of each business function identified during the Information Strategy Planning stage. Additional modeling includes a Process Dependency Diagram, which helps identify the chronological dependency and flow of processes (similar to data flow diagrams, but without showing the actual data in the flows).

3. System Design

> Concerned with *how* selected processes in the business area are implemented in procedures and *how* these procedures work. Direct end-user involvement is needed in the design of procedures. (Martin, Book I, 1989, p. 13)

During the System Design phase, the procedures required to implement the elementary processes are determined and the user interfaces (screens, reports, layout) are designed. This phase, as well as the following Construction phase, is generally accomplished using automated assistance in the form of specific CASE or integrated CASE (I-CASE) tools. This phase is typically characterized by heavy end-user involvement in the design of user interfaces.

a. Business System Design

The objective of Business System Design is the definition of the user interactions with the information system needed to conduct the business activities identified during the Business Area Analysis phase. This involves the

establishment of standards, the determination of procedures required to implement the elementary processes, the specification of user navigation through the procedures, and the design of external user interfaces (TI, 1988, p. 300).

b. Technical Design

Technical Design encompasses the environmental considerations of the target operating environment, including the particular hardware and software implementations.

4. Construction

> Implementation of the procedures using, where practical, code generators, fourth-generation languages, and end-user tools. Design is linked to construction by means of prototyping. (Martin, Book I, 1989, p. 13)

The Construction phase implements the results of the Design phase by converting the design specifications into software code. The software code is tested, as is the hardware and all inter-connections. The implementation procedures for the new system are developed, the training requirements are developed and implemented, the user and technical documentation is prepared, and the long term maintenance requirements are determined.

a. Construction

The specific code for the target environment is developed, either manually, or using an automated code generator. Initial testing of the software code is performed.

b. Transition

Transition in an information engineering environment is similar to transition in a non-information engineering environment (Martin, Book II, 1990, p. 377). The information system equipment is installed, data is ported to the new system, users are trained, and the new system is implemented. Implementation will involve one or more of several different methods of conversion, including direct cutover, parallel processing, or phased transition.

c. Production

Production refers to the development of operating and maintenance procedures and administrative policies. These include procedures and policies for normal system operation, restart and recovery operations, security, audit, and periodic maintenance (Martin, Book III, 1990, p. 395).

C. TEXAS INSTRUMENTS' INFORMATION ENGINEERING FACILITY ™

Texas Instruments' Information Engineering Facility™ (IEF™) is an integrated Computer Aided Software Engineering (I-CASE) tool that implements the information engineering concepts expressed by James Martin in his publications, and refined by James Martin Associates (TI, 1988). Texas Instruments (TI) primarily targets mainframe application environments (currently CICS, IMS/DC, TSO, and MVS/Batch, with others under development) with mainframe or PC based development environments (Clark, 1992, p. 81). IEF™

components implement the underlying information engineering methodology through the use of a central encyclopedia or data repository and toolsets for the planning, analysis, design, and construction phases of the information engineering lifecycle. Figure III.2 provides a graphic illustration of the IEF™'s support for information engineering.

1. Enterprise Integration

One of the strengths of the IEF™ CASE tool is the vertical, horizontal, and cross-enterprise integration maintained throughout the product. Each toolset is interlocked, providing integration "*within* each stage of the system life cycle, *throughout* all stages of the system life cycle, and *across* the individual life cycles of all systems". (TI-I, 1990, p. 6) Figure III.3 provides a graphical depiction of IEF™'s vertical and horizontal integration.

a. Vertical Integration

Vertical integration maintains integrity and consistency from stage to stage through tight coupling of the high-level specifications developed in the earlier stages (Planning and Analysis) and the detailed specifications developed in the later stages (Analysis and Design) (TI-I, 1990, p. 7). Figure III.2 also shows some of the coupling between stages.

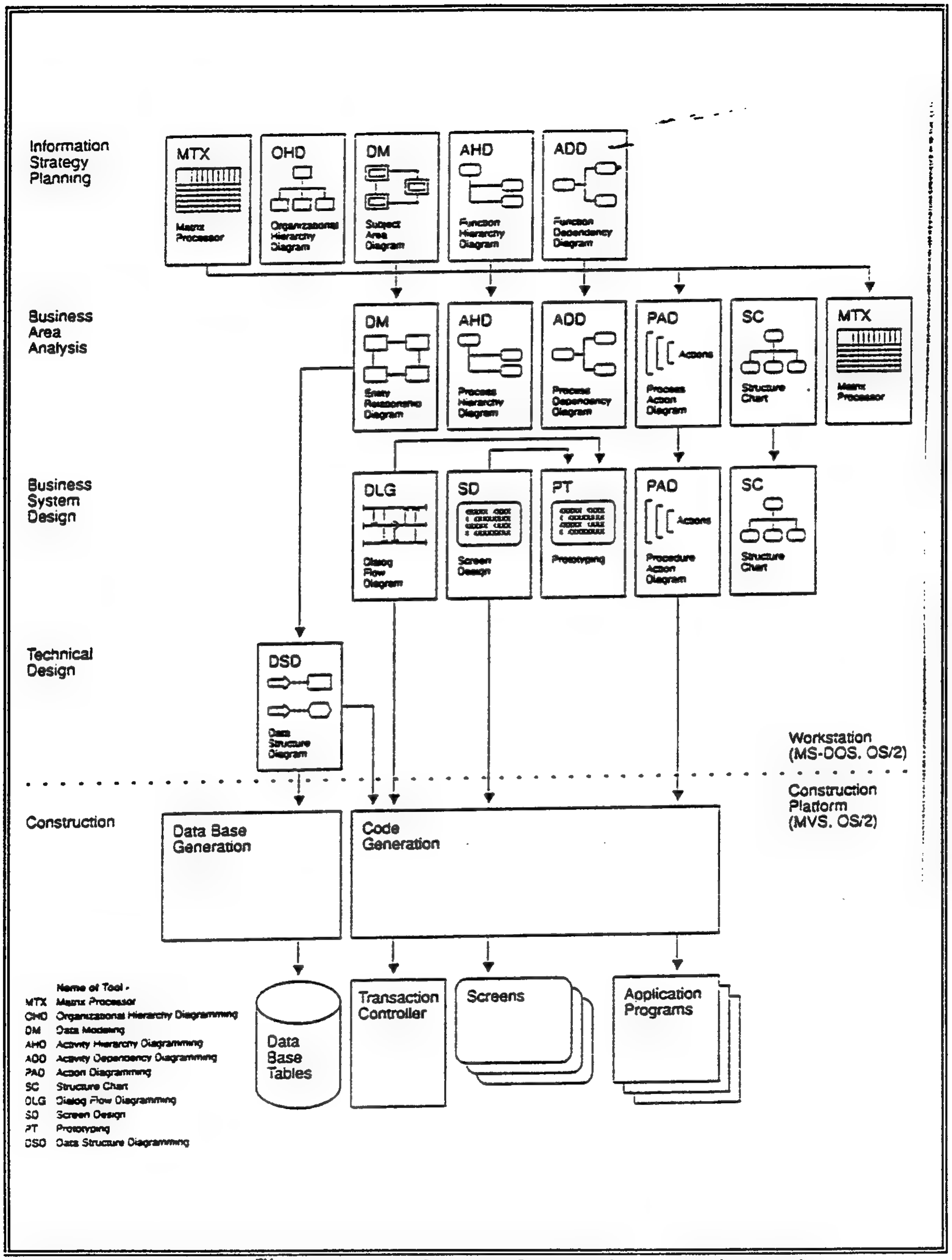

Figure III.2 IEF™ Support for Information Engineering (TI, 1990, p. 10)

	DATA	INTERACTION	ACTIVITIES
Information Strategy Planning	Subject Area Diagram	Matrices	Function Hierarchy Diagram
	Entity Relationship Diagram		Function Dependency Diagram
Business Area Analysis	Entity Relationship Diagram	Expected Effects	Process Hierarchy Diagrams
	Entity Hierarchy Diagram	Stereotypes	Process Dependency Diagrams
		Process Action Diagrams	
Business System Design	Screen Design	Procedure Action Diagrams	Dialog Flow Diagrams
		Structure Charts	
Technical Design	Data Structure Diagram		Load Module Packaging
Construction	Database Definition Generation	SQL Update/Access Statement Generation	Program/Control Block Generation

Figure III.3 IEF™ Vertical and Horizontal Integration (TI, 1989, p. 12)

(1) Information Strategy Planning. The Planning Toolset produces deliverables primarily targeted at top-level management. These deliverables provide documentation about the enterprise: a mission statement; an information needs map; a list of objectives, strategies, and critical success factors by organizational unit; an organizational hierarchy structure diagram; a high-level Entity Relationship Diagram (data model); an overall Function Hierarchy Diagram (activity

model); a set of Function Dependency Diagrams (interaction model); and other supporting matrices. (TI-MT, 1992, p. 15)

(2) Business Area Analysis. The Analysis Toolset produces deliverables targeted at end users. The deliverables include the same deliverables from the Planning Toolset; the only difference in the deliverables is the level of abstraction -- the Analysis Toolset provides significantly greater detail.

(3) Business System Design. The Design Toolset also produces deliverables targeted at end users, but at the next lower level of abstraction. The deliverables include a set of procedures and data views for each business system, and a set of user screen and report layouts.

(4) Technical Design. The Design Toolset produces deliverables targeted at trained information systems professionals. The deliverables consist of a set of Data Structure Lists and target environment-specific implementation details after the model has been tailored to a specific data base management system.

(5) Construction. The Construction Toolset produces 100% of the code required for execution of the application.

b. Horizontal Integration

Horizontal integration maintains integrity within each stage, by maintaining integrity between diagrams, tables

and lists. Through horizontal integration, consistency is maintained among the three components -- data, activities, and interactions -- at each stage of the system life cycle. The key to IEF™'s horizontal integration is the assignment of a single unique definition to each concept that is then shared among all the tools (TI, 1989, p. 6). Figure III.4 provides a graphical display of IEF™'s horizontal integration.

(1) Data. The term data represents all concepts that exist in a real or abstract sense in the enterprise environment; examples for NPS include *students, faculty members,* and *classes.*

(2) Activities. The term activities represents all functions or processes that occur within the organizational environment, such as *a student attends classes* or *a faculty member conducts research.*

(3) Interaction. The term interaction represents how activities affect data, such as how *a student completing a course* affects the *student* by requiring creation of a *student grade.*

c. *Cross-Enterprise Integration*

Cross-enterprise integration ensures consistent definitions of data and activities across all functions of the organization, at any level of detail (level of abstraction) that is provided (TI, 1989, p. 7). This consistency throughout the organization is achieved through the use of a

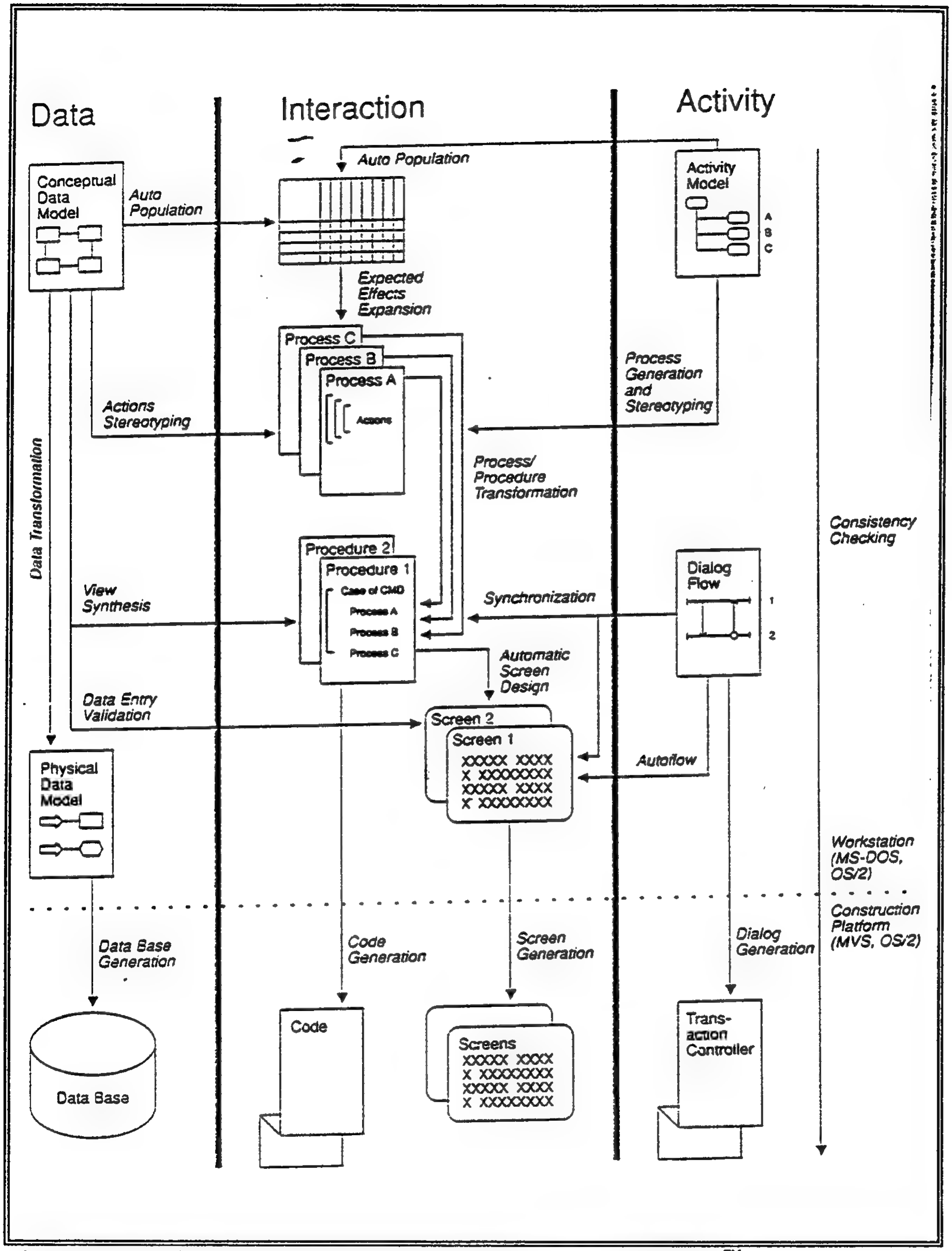

Figure III.4 Cross-Stage Automation in the IEF™
(TI, 1990, p. 13)

central comprehensive repository of systems information, which in IEF™ is known as the Central Encyclopedia. The Central Encyclopedia, or Host Encyclopedia, is essentially an IBM DB2™ system development relational data base maintained on a mainframe using the MVS operating system. The Host Encyclopedia is a schema, in the form of a highly flexible system development model, that connects the information engineering system concepts together. The Host Encyclopedia defines all of the generic classes of objects in the IEF™ architecture (such as subject areas, entity types, functions, and processes) and details their relationships to one another. Figure III.5 provides a simplified view of the Host Encyclopedia and its relationship to the modeling objects.

2. Toolsets

IEF™ provides a number of graphical modeling tools divided into subsets that correspond to the principal stages in the information engineering methodology. The toolsets are: Planning (Information Strategy Planning), Analysis (Business Area Analysis), Design (Business System Design/Technical Design), and Construction (Technical Design/Construction); other toolsets provide interfaces to the Central Encyclopedia or provide overall functions. Some of the tools are used in more than one toolset, which supports the transition from a high level of abstraction to a more detailed view of the organization as the modeling progresses. All the toolsets

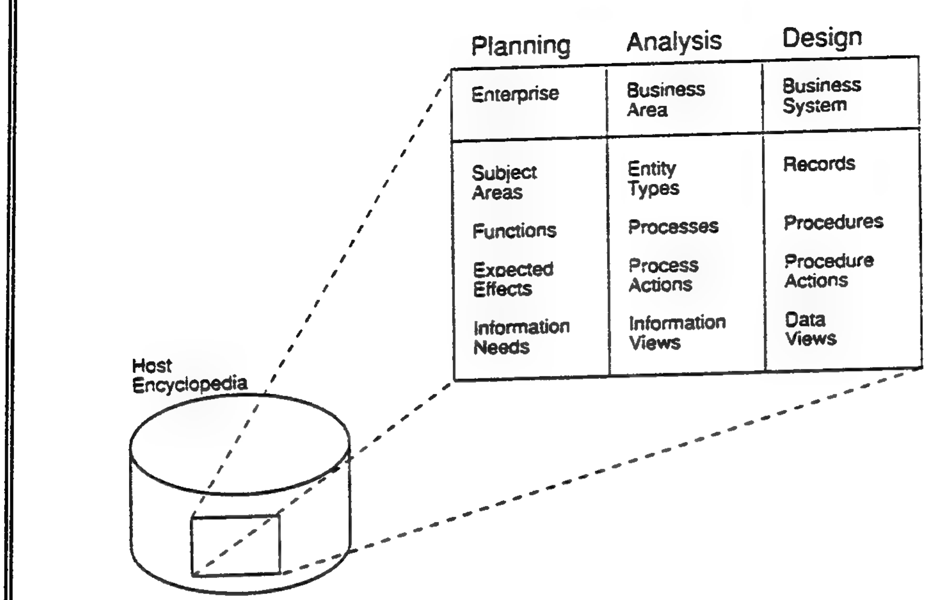

Figure III.5 Central Repository of Modeling Objects (TI, 1992, p. 65)

provide access to a comprehensive list of reports, which can be displayed, printed, or separately saved to a file. A brief description of the available tools in each toolset is provided in Appendix C (TI-8072, 1990; TI-8024, 1990; TI-8040, 1990).

IV. ANALYSIS OF NPS ENTERPRISE INFORMATION ARCHITECTURE

This chapter provides an analysis of the Naval Postgraduate School (NPS) enterprise information architecture. The analysis of the Naval Postgraduate School's information architecture uses James Martin's variant of the classical information engineering methodology as a guideline. The Texas Instruments' Computer Aided Systems Engineering (CASE) tool Information Engineering Facility™ (IEF™) is an automated implementation of Martin's methodology, and provides support for the analysis. This chapter also provides a discussion of the financial and personnel constraints for implementation of any new data management architecture.

A. NAVAL POSTGRADUATE SCHOOL BACKGROUND

The Naval Postgraduate School catalog provides an overview statement of the organization's purpose:

> The Naval Postgraduate School is an academic institution whose emphasis is on study and research programs relevant to the Navy's interests, as well as to the interests of other arms of the Department of Defense. The programs are designed to accommodate the unique requirements of the military. (NPS, 1994)

The organization's mission statement is more explicit with respect to the educational objectives:

> The mission of the Naval Postgraduate School is to provide advanced professional studies at the graduate level for military officers and defense officials from all services and other nations. The school's focus is to increase the combat effectiveness of the armed forces of

> the United States by providing quality education which supports the unique needs of the defense establishment. (NPS, 1994)

An expanded mission statement, which more accurately reflects the dual roles of education and research, exists in Secretary of the Navy (SECNAV) INSTRUCTION 1524 (May 23, 1986):

> The Naval Postgraduate School exists for the sole purpose of increasing the combat effectiveness of the Navy and Marine Corps. It accomplishes this by providing post-baccalaureate degree and nondegree programs in a variety of subspecialty areas not available through other educational institutions. NPS also supports the Department of the Navy through the continuing programs of naval and maritime research and through the maintenance of an expert faculty capable of working in, or as advisors to, operational commands, laboratories, systems commands, and headquarters activities of the Navy and Marine Corps. (NPS, 1994)

The Naval Postgraduate School's 1994 Catalog is the source for the following background information on the school's structure and organization:

The Naval Postgraduate School is administered as an activity within the Department of the Navy, and is funded by the Congress of the United States. A Graduate Education Review Board (GERB), chaired by the Chief of Naval Operations, meets annually to provide guidance and direction for the Navy's graduate education program. The GERB reviews the adequacy and stability of resources and student input, and other matters of potential interest, and is based on the annual report of the Graduate Education Review Group (GERG). A Board of Advisors, composed of distinguished professionals from all walks of life, annually assesses the Naval

Postgraduate School's mission effectiveness, and evaluates future plans, as part of their charter to assist the Superintendent on strategic matters of the Navy's Graduate Education Programs. The Navy's fully-funded graduate education program includes 78 different curricula, 35 at NPS and 36 at over 62 civilian institutions, to support 71 military billet subspecialty codes.

The Superintendent of the Naval Postgraduate School is a flag officer of the line of the U.S. Navy. In addition to serving as the NPS administrator, the Superintendent is the academic coordinator for all graduate education programs in the Navy, including fully funded graduate education programs at the Naval War College and civilian institutions, and the Area Coordinator for Naval Subarea Six. The Superintendent's principal assistant is the Provost/Academic Dean, who is the ranking member of the civilian faculty. The other principal assistants in the administrative staff include two military positions and four academic positions.

Members of the faculty are organized into eleven Academic Departments and four interdisciplinary Academic groups, each supervised by a chairman. Over 80% of the faculty are civilians of varying experience levels; the remainder are military officers.

Eleven Curricular Offices, staffed by military officers (Curricular Officers) and civilian faculty members (Academic Associates), serve three functions:

1. Academic counseling and military supervision of officer students

2. Curriculum development and management to ensure attainment of professional and academic objectives

3. Liaison with curricular sponsor representatives

Students, grouped by curricular program, are assigned to one of the Curricular Offices for program supervision and for academic and professional counseling. Numerous types of individuals attend the Naval Postgraduate School as students, including Naval officers, other U.S. military officers, international military officers, and civilian employees of the U.S. Government. The Curricular Officers ensure their curricula meet Navy requirements, and ensure proper administrative operation of their assigned offices. The Academic Associates ensure the integrity and academic soundness of the academic programs within each curriculum. Figure IV.1 presents the NPS organizational hierarchy.

The Naval Postgraduate School also serves as the host for a variety of tenant activities, including the Defense Resources Management Institute (DRMI), a DoD sponsored educational institution.

B. NPS ENTERPRISE INFORMATION ARCHITECTURE ANALYSIS

The analysis of the NPS enterprise follows the procedural steps of James Martin's version of the information engineering methodology. The Texas Instruments (TI) Computer Aided Software Engineering (CASE) tool Information Engineering

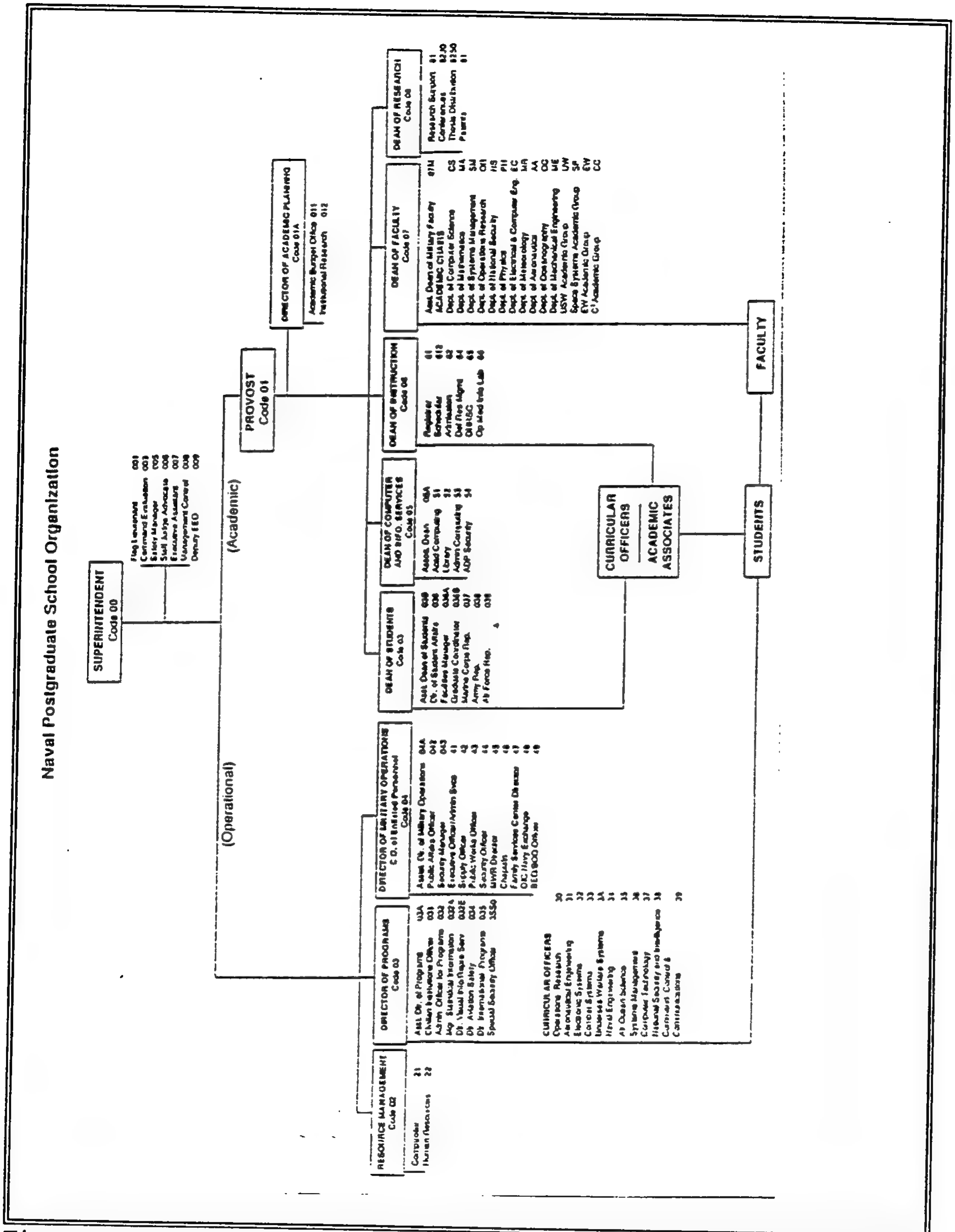

Figure IV.1 Naval Postgraduate School Organizational Chart (NPS, 1994)

Facility™ (IEF™) provides automated analytical support. The scope of the analysis includes tasks defined within the first two phases of the information engineering methodology -- Information Strategy Planning (ISP) and Business Area Analysis (BAA). The bulk of the research concentrates on the first phase, Information Strategy Planning. However, this research does not attempt to completely perform the procedures specified for either of these two phases; to do so properly within the NPS organizational environment requires significantly more resources than are currently available. The discussion of each information engineering methodology phase identifies all the tasks, and the expected level of detail, that would normally be performed as part of that phase. Analysis comments address incomplete tasks when appropriate.

1. Information Strategy Planning (ISP)

In simplest form, the objectives of the analysis in the Information System Planning (ISP) stage are:

1. Define the structure of the enterprise.
2. Define the information requirements of the enterprise.
3. Define the activities performed by the enterprise.
4. Define the data required to perform the activities.
5. Group the activities and data into natural business systems.

6. Forecast the required hardware and software facilities.
7. Supply detailed information supporting the Information Strategy Plan. (IEF™, 1991)

The deliverables for the ISP phase include four specific diagrams -- the Organizational Hierarchy Diagram (OHD), the Function Hierarchy Diagram (FHD), the Function Dependency Diagram (FDD), and the Entity-Relationship Diagram (ERD) -- and multiple supporting matrix diagrams. The *OHD* simply diagrams the organizational structure of the enterprise. The *FHD* records the high-level business functions (activities) performed by the enterprise, i.e., provides the activity component of the business model; the *FDD* records the dependencies between these business activities. The *ERD*, which is actually part of a Subject Area Diagram (SAD), graphically displays the data required to perform the activities, i.e., provides the data component of the business model. (The Subject Areas are the activities in which a business is interested.) Matrices provide mechanisms for recording business related information, such as goals, objectives, strategies, critical success factors, etc.

The ISP analysis includes the following procedural steps:

1. Collect and evaluate existing strategic plans
2. Create an overview model of the enterprise
3. Conduct business-oriented strategic analyses
4. Create a top-level analysis of corporate data

5. Refine the enterprise model and entity-relationship diagram

6. Group the enterprise model into natural clusters

7. Analyze current systems to determine what changes are needed

8. Prioritize the business areas for Business Area Analysis

Each procedural step actually consists of several individual tasks, and provides an outline for reporting the results of the analysis.[5]

a. *Evaluate Strategic Plans*

Types of strategic plans include existing strategic business plans, existing Information Strategy Planning plans, existing strategic information technology plans, existing critical success factor studies, top management goals and objectives, existing data models, and any other existing relevant plans or system architecture documents. Strategic plans generally contain one of four planning components:

Mission. The *mission* of an enterprise is the highest-level statement of objectives. It gives a broad description of the purpose and policy of the enterprise.

Objectives. *Objectives* are general statements about the directions in which a firm intends to go, without stating specific targets to be reached by particular times.

[5] A full outline of a suggested procedural steps for Information Strategy Planning is in James Martin's *INFORMATION ENGINEERING Book II: Planning and Analysis* (Prentice Hall, 1990)

> **Goals**. *Goals* are specific targets that are intended to be reached by a given time. A goal is thus an operational transform of one or more objectives.
>
> **Strategy**. A *strategy* in an enterprise is a pattern of goals, policies, and plans that specify how an organization should function over a given period. A strategy may define areas for product development, techniques for responding to competition, means of financing, size of the organization, image the enterprise will project, and so on. (Martin, 1990b, p. 70)

Additionally, different goals can have different timeframes associated with them, otherwise known as "planning horizons." Strategic goals generally relate to long-term planning of five years or more. Tactical goals generally relate to short-term planning of about one year or less.

As previously discussed, the Naval Postgraduate School's expanded mission statement best summarizes the overall objectives for the enterprise, and is repeated here:

> The Naval Postgraduate School exists for the sole purpose of increasing the combat effectiveness of the Navy and Marine Corps. It accomplishes this by providing post-baccalaureate degree and nondegree programs in a variety of subspecialty areas not available through other educational institutions. NPS also supports the Department of the Navy through the continuing programs of naval and maritime research and through the maintenance of an expert faculty capable of working in, or as advisors to, operational commands, laboratories, systems commands, and headquarters activities of the Navy and Marine Corps. (NPS, 1994)

In order to accomplish this mission, NPS has approved a strategic vision for the future, known as the *NPS Vision 2000*. Figure IV.2 describes the vision statement. A set of *Guiding Principles*, developed by the NPS Executive Steering Committee, supports the organization's move toward

NAVAL POSTGRADUATE SCHOOL VISION 2000

It is NPS's vision to be recognized as the graduate school of choice for defense establishment students and as a premier research university at home and abroad.

a. Our students will find the school academically challenging and their curricula unique. We will ensure a maximum value-added learning environment for each student.

b. Our programs will continue to grow to met the emerging specific needs of all services, DoD and the government as consistent with our mission. The breadth of sponsorship for these curricula will continue to grow.

c. The highest quality of instruction will remain a paramount objective.

d. Students will view NPS as a valuable step in their preparation for joint and combined service.

e. Our research will continue to be recognized throughout the government as providing valuable, responsive and cost effective products, relevant to current and future defense applications. We will remain on the leading edge of technology, management and warfighting improvements.

f. Our student theses will be valued throughout DoD as thought provoking, program-enhancing, and contributing to the solving of DoD problems.

g. Our faculty will be even more sought after as participants in the most prestigious national and international research activities, and for high level DoD positions and consultations.

h. NPS postgraduate education will continue to stand out as a key element in the career of military officers and will enhance their warfighting capability and professional development.

i. NPS will be a nationally recognized leader in applying TQL to the university environment and in both recognizing and encouraging the contributions and development of all its employees. (NPS, 1994)

Figure IV.2 Naval Postgraduate School Vision 2000

the vision. Figure IV.3 provides these guiding principles. Together, the NPS Vision 2000 and the Guiding Principles provide a top-level list of objectives.

In addition to the overall NPS strategic vision, other sources of objectives exist. For example, the NPS Computer Advisory Board (CAB) proposes an Information Systems Vision Statement. The draft proposal contains three

Quality comes first. As our products and services are viewed, so are we viewed. We will achieve quality through daily emphasis on continuous improvement of our products, services and processes.

Our customers are the focus of all we do. We treat our most important customer, students, and our other external and internal customers with courtesy, compassion and respect. Maintaining total customer satisfaction is our goal, and we measure it frequently and post measurement results everywhere.

Knowing what the customer wants is critical to our success. Everyone regularly listens to their customers and openly shares what they hear and learn about customer needs. We are aware of our responsibilities as servants of the people.

Quality is everybody's responsibility. The entire chain of command is committed to the development of every student and NPS employee. Everyone is empowered to make decisions in the best interests of our mission and the command as a whole, putting aside parochialism. Self-inspection and responding to direct feedback from customers are our primary quality improvement mechanisms.

We deal with each other -- customers, co-workers and the community -- with integrity and respect. our doors are open to men and women alike without regard to race, color, religion, handicap, or national origin.

Trust and sensible judgement, not micro-management, guide people's actions. We believe that everyone is capable of superior day-to-day performance. Everyone makes decisions based on the best available information and considers the impact on those affected. We trust one another to behave and make decisions consistent with our values, policies and guidelines, without reliance on the choking rules of micro-management.

All successes, however small, deserve immediate recognition. We care for each other just as we care for our customers. The innovation, creativity and expertise of our faculty, staff and students are valued and rewarded. We hold frequent celebrations of success throughout the organization.

Teamwork is critical to our success. Through faculty, staff and student teamwork and involvement, we continually improve our products, services and processes. We value the synergism between students, faculty and staff. Teams are held accountable and teams, not just individuals, are rewarded for accomplishments.

Innovations can come from anybody, anywhere, anytime!

We encourage creativity. Everyone at NPS has the potential to be a significant contributor to improvement and the source of new productive ideas. We approach each new task or challenge with the view that every idea deserves serious consideration.

Encouraging risk taking and tolerating failure are a must if we are to be innovative. All hands are willing to root out the ways they limit or deceive themselves and others. We encourage everyone to try new ways of operating. We constantly tell each other that it's okay to make mistakes if we can learn from them.

Bureaucratic structures and procedures are the enemy! Everyone regularly challenges theories of why things are the way they are. Reducing and simplifying paperwork and eliminating unnecessary procedures are constant top management agendas.

Infrastructure development should lead, not lag, projected growth. Investments in training, technology, and facilities in advance of expected program growth are made when financially possible. Faculty and staff are constantly encouraged to improve their leadership skills and technical competence through training and education.

Figure IV.3 Naval Postgraduate School Guiding Principles

components: a draft vision statement, a proposed implementation strategy, and preliminary implementation goals. Figures IV.4, IV.5, and IV.6 provide a summary of the key

points in each section of the draft NPS Information Systems Vision statement. The CAB also proposes a draft set of *Principles for NPS Information Resource Management*, based on the DoD's Principles for Information Management found in DoD Directive 8000.1(D). Figure IV.7 presents these proposed principles.

b. Create an Overview Model

As previously mentioned, Figure IV.1 provides a chart of the organizational structure. Tab A of Appendix D provides the version of this organizational chart that was entered into IEF™ as the Organizational Hierarchy Diagram (OHD). The organizational chart in Figure IV.1 provides greater accuracy with respect to the lines of authority due to limitations in the IEF™ OHD diagramming tool, which prevents multiple lines of authority to exist in an organizational diagram.

An overview model also includes a high-level description of the functional hierarchy. Generally, a functional hierarchy consists of *functions* at the top level (Information Strategy Planning), *processes* at the second level (Business Area Analysis), and *procedures* at the third level (Business System Design) of the information engineering pyramid. *Functions* generally consist of a group of activities that together support one aspect of the enterprise mission; functions are ongoing and continuous, not based on

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NAVAL POSTGRADUATE SCHOOL INFORMATION SYSTEMS VISION STATEMENT

1. We envision NPS as an integrated organization well-positioned to fulfill its mission and meet the needs of the campus community. In this vision, the computing and information resources of the campus will be integrated in such a way as to maximize accessibility and ease of use. All of these resources of the campus should be available to those who have a need for them. This vision must encompass the following elements, which cover the primary functions of the School:

> **Instruction:** Promote excellence in the teaching process by use of computer assets in and out of the classroom;
>
> **Research:** promote excellence in research by providing the most advanced computational systems and other resources possible in support of faculty and student research;
>
> **Administration:** Support efficient administrative procedures for students, faculty, and staff;
>
> **Library and Computer Center:** Provide computational resources and computer-based information services and serve as an electronic gateway to information resources on- and off-campus.

2. We envision that the School will provide students, faculty, and staff with ready access to and use of modern information resources.

3. We envision that the School will provide a robust secure computing capability for classified work.

4. We envision that the major costs for a baseline level of computing support will be included as part of the normal NPS investment and operating costs. This includes costs for administrative and student access, as well as systems necessary for faculty instruction and research.

5. We envision that the computer architecture at NPS will be that of fully-distributed systems, which are interconnected to maximize shared utilization of campus resources. effective centralized hardware and software support for these systems will be provided.

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Figure IV.4 NPS Information Systems Vision Statement (NPS-CAB, 1993)

organizational structures, and categorize *what* is done, not *how*. On the other hand, *processes* are specified enterprise

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NPS IS Vision Implementing Strategy

1. The Dean of Computer and Information Services (Code 05) will coordinate the information systems and resources on the campus.

2. The Dean of Computer and Information Services will establish and maintain a long-range plan for campus computing and information resources.

3. The long-range plan will be prepared with the advice of the Computer Advisory Board (CAB).

4. The planning process will involve consultations with all the end-users.

5. The Information Resources Management Executive Board (IRMEB) will approve the Life Cycle Management Plan, and will have the decision-making power and authority to allocate resources.

6. NPS will actively recruit qualified information resource support personnel, and support their continued development and growth of their technical expertise.

7. Instruction will be supported by the provision of computing and multi-media assets in classrooms and laboratories as appropriate.

8. Research computing will be supported at the most modern possible level.

9. The administrative strategy for NPS is to develop an integrated system designed to minimize duplicative efforts.

10. NPS will develop an appropriate centralized computing support system to provide baseline assistance to end-users.

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Figure IV.5 NPS IS Vision Implementation Strategy (NPS-CAB, 1993)

activities that are executed repeatedly; processes can be described in terms of inputs and outputs, have definable

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NPS IS Vision Implementation -- Initial Goals

1. Each curriculum review from 1994 through 1996 will evaluate NPS's progress toward providing students opportunities to acquired computer and information resources skills to meet their professional career requirements.

2. By October 1994, every faculty and staff member will have access from their desktop to networked computing resources sufficient for their needs.

3. Each faculty and staff member will have access to a campus-wide electronic mail system by October 1994.

4. Campus network bandwidth will continue to improve until a bandwidth of 100 Mbps is available to the desktop by October 1995.

5. The School will provide access to worldwide networks of current importance.

6. Scientific visualization facilities will be maintained that are capable of displaying and interpreting the large volume of results generated by large-scale simulations and models.

7. NPS will develop support for multi-media applications.

8. Electronic document interchange will replace routine paper transactions.

9. Site licenses will be obtained for the software packages commonly used on campus.

10. The Library will develop an on-line catalog as a campus-wide information resource accessible of the network by October 1994.

11. The Library and Computer Center will implement a Campus Wide Information System (CWIS) by October 1994.

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Figure IV.6 NPS IS Implementation Goals (NPS-CAB, 1993)

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Principles for NPS Information Resource Management

1. Simplifying business practices through elimination and integration takes precedence over automation, whether developing new or enhancing existing information systems.

2. Before information systems are developed, a plan and a business case must first be prepared. business methods must be documented with process models and validated before being automated.

3. Priority will be given to developing and enhancing IS that contributes directly to corporate business strategies and effectiveness. Data processing and communications efficiency will not be the prime deterrent.

4. NPS users are responsible for the success of their information systems and accountable for the accuracy of their data and the cost of IS. That requires that the development of each data model, process model, and information system be led by a functional project manager. once developed, each model and system should be operated and continuously improved functional manager stewardship.

5. Common information systems will be deployed among all operating groups unless specific analysis establishes that they should be unique.

6. NPS and Navy data standards must be followed.

7. Data will be entered only once.

8. Data will be accessible to all authorized users, while being safeguarded from unintentional or unauthorized alteration, destruction, and disclosure. All data maintained by parts of the NPS organization are considered to be "corporate data". That is, available to any within the organization who required it. Responsibility for back-up, accuracy, entry, use, etc. will be assigned to organizational entities, but the data is owned by the larger corporate base.

9. The architecture of the computing and communications infrastructure will be transparent to the information systems that rely on it.

10. Life Cycle Management and Security Management will be in accordance with (IAW) established DoD and DoN directives.

11. Implementation of software solutions will maximize use of off-the-shelf rather than uniquely designed in house or contracted.

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Figure IV.7 Draft Principles for NPS IRM (NPS-CAB, 1993)

beginning and ending points, and like functions, are not based on organization structures, and identify *what* is done, not *how*.

The two major business functions of the Naval Postgraduate School are education and research. However, in order to provide a complete model of the NPS enterprise, the NPS functions performed in support for the Superintendent's collateral duties must also be included. Therefore, the Superintendent-specific duties (such as Navy academic coordinator and Naval Subarea Six coordinator) combine with the NPS-specific business functions in the analysis. A bottom-up analysis of the functions performed at NPS provides the basis for the activity model. The primary reference sources are the *NPS Standard Organization and Regulations Manual (SORM)*, NAVPGSCOLINST 5400.2C (22 August 1990), and a draft of the next *SORM* revision, NAVPGSCOLINST 5400.2D; these are supplemented by interviews with selected senior and middle management personnel. Aggregation of the results provides a top-level overview of the functional areas at NPS. Thus, the highest-level of the function or activity model contains the following three functional areas, shown in Figure IV.8: *Coordinate Academic Programs*, *Coordinate Subarea Six*, and *Perform All Assigned Duties*.

For purposes of this analysis, the primary interest lies in the *Coordinate Academic Programs* functional

NAVAL POSTGRADUATE SCHOOL ACTIVITY MODEL
ACTIVITY HIERARCHY

SUPERINTEND NPS

COORDINATE ACADEMIC PROGRAMS

COORDINATE SUBAREA SIX

PERFORM ALL ASSIGNED DUTIES

Figure IV.8 NPS Activity Hierarchy Diagram (AHD) -- Top Level

area. *Coordinate Academic Programs* decomposes to provide the high-level functions shown in Figure IV.9. Tab B of Appendix D provides a description of each of these top-level functions.

One noted analytical deficiency is that this high-level functional model does not follow the DoD Enterprise Activity Model format. The reason for this discrepancy is straight-forward: the list of functions performed at NPS derive from a bottom-up analysis vice a top-down analysis, and this project makes no attempt to integrate the two analysis methods. Additionally, the unique nature of the Naval Postgraduate School as both a military and an academic organization, and the specialized business functions that result from this combination, prevents neat casting of the NPS business functions into the DoD Enterprise Activity Model functional categories. In order to fully conform to DoD

NAVAL POSTGRADUATE SCHOOL ACTIVITY MODEL
ACTIVITY HIERARCHY

- SUPERINTEND NPS
  - COORDINATE ACADEMIC PROGRAMS
    - ADMINISTER EDUCATION PROGRAMS
      - ADMINISTER FULLY-FUNDED PROGRAMS
        - EXERCISE BUDGETARY CONTROL
        - MANAGE ALL PROGRAM CURRICULA
        - ADMINISTER NPS PROGRAMS
          - MANAGE ALL NPS RESOURCES
          - ADMINISTER NPS ACADEMIC PROGRAMS
          - ADMINISTER NPS OFFICER STUDENTS
          - PROVIDE NPS NON-ACADEMIC SUPPORT
          - ADMINISTER NPS RESEARCH PROGRAM
          - ADMINISTER AVIATION SAFETY PROGRAM
          - DIRECT DRMI
        - ADMINISTER OTHER USN SCHOOL PROGRAMS
        - ADMINISTER CIVILIAN INSTRUCTION PROGRAMS
      - ADMINISTER CONTINUING EDUCATION PROGRAMS
      - CONDUCT OTHER INSTRUCTION AS DIRECTED
    - PROVIDE INSTRUCTION TO STUDENTS
    - KEEP CNO ADVISED
  - COORDINATE SUBAREA SIX
  - PERFORM ALL ASSIGNED DUTIES

Figure IV.9 NPS Activity Hierarchy Diagram (AHD)
Elementary Functions

policy, the NPS functions should be assigned to the closest corresponding functional areas and functional activities

specified in the DoD Enterprise Activity Model. This integration task is left for future analytical endeavors.

A Function/Organization Unit matrix, Tab C of Appendix D, records the involvement of each organizational unit with a specific function. A limitation of the IEF™ restricts the use of functions in matrices to the elementary (lowest level in any hierarchy) functions; therefore, several of the functions shown in Figure IV.9 are absent from the Function/Organization Unit matrix. This is an unfortunate result of an artificiality of this analysis. This analysis combines elements of the BAA phase (function decomposition) with the elements of the ISP phase (function definition) in order to achieve sufficient detail to provide an opportunity for analysis of the information architecture model. System analysts generally avoid this problem by only specifying one level of functions within each functional area in the ISP phase, not multiple levels as in Figure IV.9.

The analysis of the involvement of Organizational Units with Functions in the matrix uses the following codes:

9: Executive or policy-making AUTHORITY

8: Direct management RESPONSIBILITY

7: Technical EXPERTISE

6: Actual execution of the WORK

X: INVOLVED in the function

This matrix is further discussed in a later section.

c. Conduct Business-Oriented Strategic Analyses

Four types of business-oriented strategic analyses provide additional supporting data. Analysts often perform these analyses in parallel with the other analyses within the Information Strategy Planning stage.

(1) Conduct Analysis of Goals and Problems. The earlier section on strategic planning discusses several documents which describe the high-level objectives of the command. Unfortunately, none of the more commonly found strategic planning documents identified -- with the exception of the NPS mission, NPS Vision 2000, and Guiding Principles -- exist. Numerous efforts are underway to develop long-range strategic plans under the leadership of the NPS Executive Steering Committee, but they have not yet reached fruition.

(2) Conduct Critical Success Factor Analysis. Critical Success Factors (CSF) are factors that have a major influence, positive or negative, on the attainment of an enterprise objective or goal. Another way to look at CSFs is "Goals are *ends;* CSFs are *means* to those ends." (Martin, 1990b, p. 89) Normally, written documentation throughout the enterprise identifies and defines the CSFs. When documentation does not exist, the other principal method for determining CSFs are analyst interviews of senior management

personnel. The CSF analysis generally creates and documents a list of critical information, a set of critical assumptions, and a set of critical decisions.

No specific documentation exists that identifies the CSFs for NPS. The Executive Steering Committee identifies a number of strategic issues witihin six different business areas -- Curriculum/DoD Students, New Markets, Budget, Faculty, Sponsors, and Other -- and a new set of philosophical guidelines to complement the NPS mission, Vison 2000, and Guiding Principles (NPS, August 23, 1994). However, using the previous definitions for *mission, strategy, objectives, goals,* and *CSFs,* these strategic issues are not really CSFs; they are objectives, interspersed with one or two goals.

Interviews with senior and middle management personnel at NPS reveal that one recurring critical success factor is information: the need to have the right information at the right time, in the right format.

(3) Conduct Technology Impact Analysis. This subtask provides a determination of the potential impact of information technology on the enterprise, and generally consists of a literature search for emerging information technologies and applications. Chapter V discusses the results of the technology review.

(4) Conduct Strategic Information Systems Study. Strategic information systems are the mission-critical systems which directly enable an organization to accomplish a mission. Therefore a strategic information systems study addresses the ways in which information systems can enhance an organization's operations. Although this analysis did not conduct a strategic systems study, the proposed NPS Information System Vision and its implementing strategies and goals provides an excellent starting point.

d. Create a Top-Level Corporate Data Model

The highest-level view of the data model has only two Subject Areas: the Naval Postgraduate School and Other Organizations. Decomposing the Naval Postgraduate School subject area, the top-level view of the model consists of thirteen subject areas; some of these subject areas are even further subdivided, containing additional subject areas. Figure IV.10 shows the thirteen primary subject areas; Figure IV.11 shows the expanded diagram including all subject areas.

Unlike the activity model, the thirteen primary subject areas for the NPS data model directly correlate to the top-level entity types in the DoD Enterprise Data Model (DoD, 1993). Although the data model analysis also is a bottom-up analysis, the number and classes of data entity types supports

NAVAL POSTGRADUATE SCHOOL DATA MODEL
SUBJECT AREAS

NAVAL POSTGRADUATE SCHOOL

- AGREEMENTS
- CAPABILITIES
- FACILITIES
- FUNDS AND BUDGETS
- GUIDANCE
- LOCATIONS
- MATERIEL
- NPS ORGANIZATIONS
- PEOPLE
- PLANS AND PROGRAMS
- REAL ESTATE
- SITUATIONS

OTHER ORGANIZATIONS

Figure IV.10 NPS Data Model Subject Areas -- Top Level

easier integration with the DoD Enterprise Data Model. In this manner, the NPS data model meets DoD guidance for use of the DoD Enterprise Model.

Each subject area contains its associated entity types; the top-level Entity-Relationship Diagram (ERD) contains fourteen entity types. At the next level of detail used in the analysis, the ERD contains 61 entity types, listed in Figure IV.12. Additionally, some of the entity types at this level have entity subtypes. Tab D of Appendix D contains a listing of all the subject areas, entity types, entity subtypes, and the relationships between entity types. Figure IV.13, although difficult to view, graphically depicts these objects, and represents the extent of the level of detail used

NAVAL POSTGRADUATE SCHOOL DATA MODEL
SUBJECT AREAS (EXPANDED)

NAVAL POSTGRADUATE SCHOOL
- AGREEMENTS
- CAPABILITIES
- FACILITIES
- FUNDS AND BUDGETS
  - BUDGETS
  - FUNDS
- GUIDANCE
- LOCATIONS
- MATERIEL
- NPS ORGANIZATIONS
- PEOPLE
  - FACULTY
  - STAFF
  - STUDENTS
  - NPS VISITORS OR GUESTS
- PLANS AND PROGRAMS
  - PLANS
  - PROGRAMS
- REAL ESTATE
- SITUATIONS

OTHER ORGANIZATIONS

Figure IV.11 NPS Data Model Subject Area Decomposition

for this analysis. Tab E of Appendix D contains a viewable full size foldout of the diagram.

A Function/Data Entity Type matrix describes the involvement of each data entity type with each function. Tab F of Appendix D provides the Function/Data Entity matrix. Since the IEF™ tool only diagrams entity types, not subtypes, the matrix does not include all the entity subtypes depicted in Figures IV.13 and Tab D. The expansion from fourteen entity types to 59 entity types is an artificiality of the

NAVAL POSTGRADUATE SCHOOL DATA MODEL
DATA ENTITY TYPES

Naval Postgraduate School	Agreement	Automated Info System Resource
Academic Course Instruction	Civilian Institution Instruction	Curriculum Instruction
Short Course Instruction	Military Ops Support Capability	Faculty Research
Institutional Research	Student Research	Facility
Departmental Budget	NPS Budget	Organizational Code Budget
Research Budget	Appropriated Fund	Donated Fund
Non-Appropriated Fund	Reimbursable Fund	Revolving Fund
Special Fund	DoD Guidance	DoN Guidance
Federal Government Guidance	Naval Subarea Six Guidance	NPS Policy Guidance
Location	Material	Academic Dept or Group
NPS Organizational Code	Tenant Command	Civilian NPS Faculty
Military NPS Faculty	Civilian NPS Staff	Military NPS Staff
Civilian NPS Student	Military NPS Student	NPS Visitor or Guest
Academic Plan	Administrative Plan	Curricular Plan
Departmental Plan	Financial Plan	Mil Ops Support Plan
NPS Plan	Organizational Code Plan	Academic Program
Administrative Program	Curricular Program	Departmental Program
Financial Program	Mil Ops Support Program	NPS Program
Organizational Code Program	Land	Situation
Organization		

Figure IV.12 NPS Data Model Data Entity Types -- Top Level

analysis to overcome the limitations of the automated tool in the ISP phase -- the 59 entities actually include all the entity subtypes of the original fourteen entity types.

The matrix uses the following codes, arranged in order of precedence:

C: Create

D: Delete

U: Update

R: Read

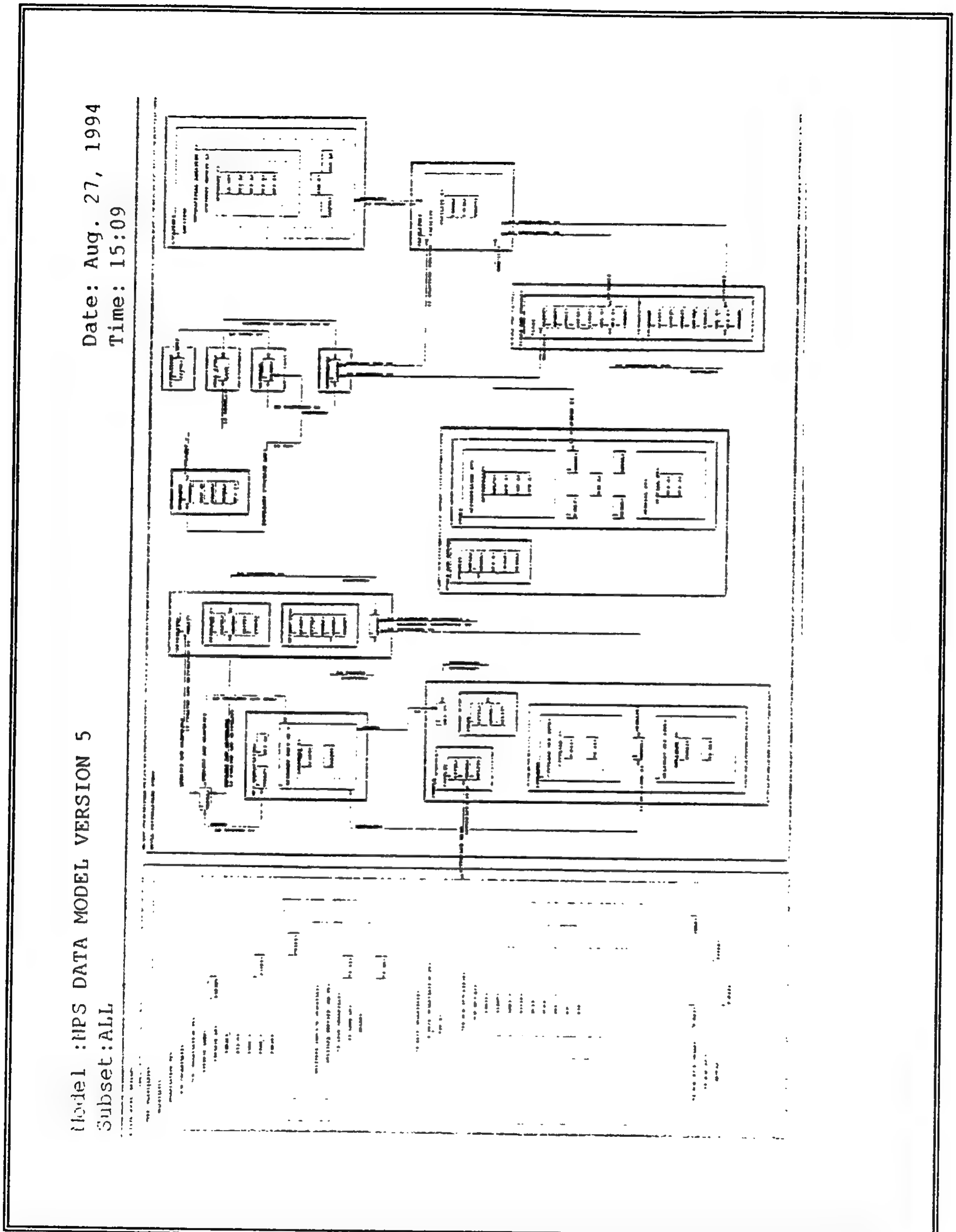

Figure IV.13 NPS Data Model Entity-Relationship Diagram Detailed View

The *Create* relationship implies the ability to *Delete, Update,* or *Read;* the *Delete* relationship implies the ability to *Update* or *Read;* and the *Update* relationship implies the ability to *Read.* The codes apply to the creation, deletion, update, and read of specific data instances of each data entity type, not to the object itself. For example, the Admissions Office does not "create" a Student, but the office does create an instance in a database of a Student when one is admitted to the school.

The matrix includes a number of blank columns, which correspond to "generic" entity types. This condition is the result of attempts to limit the level of detail in this phase while still providing enough detail to perform some analysis. These generic entity types result from artificially promoting the entity subtypes and not redefining the relationships among the original entities as relationships among all the newly promoted entities. For example, a *Person* entity type has four subtypes -- *Faculty Person, Staff Person, Student Person,* and *Visitor Person* -- but the relationships with other entity types are at the *Person* level. Promoting these entity subtypes technically requires re-establishing the *Person* relationships at the *Faculty, Staff, Student,* and *Visitor* level; this level of detail is excessive for a top-level data model in the ISP phase. Therefore, the "generic"

entity types represent the original entity types before the promotion of subtypes, and provide the relationship links with other entity types.

The Data Entity/Organization Unit Matrix, Tab G of Appendix D, uses the same CRUD code to display the relationship between each data entity and the organizational units.

e. *Refine the Enterprise Model*

This procedural step generally provides an opportunity for end-users to review and make improvements to the enterprise model. The potential end-users at NPS include representatives from every major organizational unit. Since insufficient researcher resources prevents any attempt to achieve this level of coordination for feedback on the enterprise model, an academic approach using selected faculty members as technical experts provides the relevant feedback and refinement iterations for this analysis.

f. *Perform Cluster Analysis*

The Function/Entity Type Matrix in Tab H of Appendix D shows the results of using IEF™'s clustering algorithm on the *Create* relationships in the matrix in an attempt to determine natural system boundaries. The groupings "... represent logical information subsytem groupings with responsibility for creating and maintaining the various classes of data" (Martin, 1990b, p. 174). Further analysis of

the clustered matrix assigns the functions which remain outside of the defined groupings to a particular cluster to complete the business area boundary definition. As a result of this analysis, the clustered matrix defines eight business areas. Figure IV.14 defines these business areas, and shows which of the elemental top-level functions (from Figure IV.9) are assigned to each area. The overlapping ranges of entity types created by different functions indicates some functions are grouped incorrectly within a functional area. However, at this top level in the model the functions are too aggregated to determine which functions should be relocated; further decomposition of the functional hierarchy would allow better analysis. The naming convention for the business areas generally is arbitrary, but follows along the lines of the top-level functional areas. The business areas designated in this phase are the basis for further analysis in the BAA phase.

Some organizations also perform a function dependency analysis during this portion of the ISP phase, resulting in a Functional Dependency Diagram (FDD); however, most organizations defer this analysis to the BAA phase, due to the high-level overview nature of the ISP phase. This particular analysis effort forgoes the function dependency analysis entirely.

NAVAL POSTGRADUATE SCHOOL ACTIVITY MODEL
BUSINESS AREAS

ACADEMIC PROGRAM ADMINISTRATION
- Administer NPS Academic Programs
- Keep CNO Advised

NON-ACADEMIC SUPPORT OPERATIONS
- Provide NPS Non-Academic Support

RESEARCH PROGRAMS
- Administer NPS Research Program

STUDENT ADMINISTRATION
- Administer NPS Officer Students

RESOURCE MANAGEMENT
- Manage All NPS Resources
- Exercise Budgetary Control

COURSE INSTRUCTION
- Conduct Other Instruction as Directed
- Administer Aviation Safety Program
- Direct DRMI
- Administer Continuing Education Programs
- Administer Other USN School Programs
- Administer Civilian Institution Programs
- Provide Instruction to Students

CURRICULAR PROGRAM MANAGEMENT
- Manage All Program Curricula

NAVAL SUB-AREA SIX COORDINATION
- Coordinate Subarea Six
- Perform All Assigned Duties

Figure IV.14 Business Areas and Functions

g. Analyze Current Information Systems

This procedural step defines the existing information systems within the organization, and documents the relationships among these systems and organizational units,

entity types, and business functions. The analysis uses matrices for each pair-wise comparison, which can be clustered to help define business areas. Tabs I, J, and K of Appendix D provide these matrices.

Due to analyst resource constraints and the high-level overview nature of the analysis, the listing of the organization's information systems is not comprehensive or complete; the listing is only a representational sample of NPS's information systems. Therefore, the matrices are not useful for further analysis until all the systems at NPS are identified and entered into the list.

h. Prioritize Business Areas

During this procedural step, analysts typically prioritize development of the business areas by ranking each area based on a number of factors: return on investment, demand, organizational impact, existing systems, likely success, resources required, and concurrent implementations. Once the business areas are prioritized, system development shifts to the BAA phase for each business area.

This project does not include any analysis for prioritizing business areas for system development.

2. Business Area Analysis (BAA)

The objectives of the Business Area Analysis are:

1. Fully identify and define the type of data required by the business.

2. Identify and define the business activities that make up each business function.

3. Define the necessary sequence of business activities.

4. Bring the results of data analysis together with activity analysis to illustrate how changes to the process definition affect data analysis.

5. Provide the basic information necessary to define data structures.

6. Provide the starting point for transformation to Design and the definition of procedures. (IEF™, 1991)

In short, the principal objective of the Business Area Analysis phase is to refine in detail a specific portion of the Information Architecture established during the Information Strategy Planning stage. Emphasis is on the entity types and functions within a specific Business Area. The deliverables for this phase consist of an ERD, a Process Hierarchy Diagram (PHD), and a Process Action Diagram (PAD).

The *ERD* in this phase is simply a refinement of the ERD from the ISP stage to create a more detailed definition of the data entity types, their relationships, and other characteristics (attributes).

The *PHD* is likewise a refinement of the FHD from the ISP phase; the functions decompose into processes until the elementary processes are defined. The corollary to the function dependencies recorded in the FDD is the process dependencies recorded in the PDD.

The *PAD* is the result of interaction analysis which details how processes affect data, and graphically displays

the inputs into an elementary process, the action performed by an elementary process, and the output resulting from the execution of an elementary process.

BAA establishes *what* data and *what* processes are required to operate the enterprise. BAA does not establish *how* procedures operate. BAA creates models (or expands models from the ISP phase) of the fundamental data and processes which are necessary for the organization, independent of technology, independent of the current systems, and independent of the current organizational structure. The procedural steps for the BAA phase are:

1. Create a preliminary data model
2. Create a preliminary process model
3. Successively refine the information

The data model and the process model undergo iterative refinements, until a complete representation of the data, the elementary processes, and their relationships is achieved. An elementary process is a process that cannot be decomposed further without stating how a procedure is carried out. Examples of elementary processes are: create instance of student, update instance of student, and delete instance of student.

This project only performs selected portions of the first iteration within the BAA phase; the first iteration applies to the enterprise as a whole, not to any particular business area. The discussion of the analysis from this phase

consists of three components: the data model, the functional model, and the relationship model.

a. *Data Model (Entity Relationship Diagram)*

Refinement of the relational data model includes adding keys and other attributes to each data entity type, adding intersection entity types where appropriate, and ensuring that the attribute groupings are in Fourth Normal Form.[6] This project provides only a top-level data model, and the BAA phase does not significantly refine the data model beyond the ISP phase. Each data entity type acquires one or two attributes; these attributes are an identification code that serves as the key, and/or a classifying attribute that determines an entity subtype. Tab L of Appendix D provides a listing of each entity type, entity subtype, and their attributes.

b. *Functional Model (Process Hierarchy)*

Since the functional model was created through bottom-up analysis and then aggregated, multiple levels of functional decomposition already exist. In order to analyze the functions at the highest level, most of the decomposed functions were coded as processes. In reality, some of these activities are functions and some are processes. (Recall the

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[6] Fourth Normal Form is loosely defined as follows: "Every data item (attribute) in a record is dependent on the key, the whole key, and nothing but the key." (Martin, 1990b, p. 236)

earlier definitions of *functions* and *processes*.) For purposes of this analysis, no distinction between functions and processes is made for the first (and only) iteration.

Many of the processes in the decomposed layers appear to coincide with the levels in the organizational structure hierarchy. The aggregation (or decomposition) of some processes does follow organizational structure lines, but this is due to functional grouping, and not necessarily due to organizational unit grouping. Further evidence of this phenomenon appears in the description of some activities, which uses an organizational position to describe a particular function. An example of this type of description is an activity that is listed as "Serve as primary assistant to ...." Further decomposition of the activity model removes these types of discrepancies by specifying the elementary processes involved in that type of activity or function. Tab M of Appendix D provides the first iteration graphical decomposition of the activity model; Tab N of Appendix D provides a complete listing of all activities, their descriptions, and their subordination to other activities.

As in the ISP phase, this project does not conduct any process dependency analysis.

c. Relationship Model

Generally, the BAA phase includes refinement of all existing matrices, and the creation of matrices that

involve processes instead of functions. Due to the nature of the first BAA phase iteration, which involves an enterprise-wide vice business area approach, and the tremendously large number of processes defined, this project does not attempt to define the inter-relationships between processes and other objects.

d. Results of Analysis

ISP and BAA analyses not only model an existing organization, but also provide a mechanism for determining if the organization should be changed, and if so, how. In this regard, analysis of the matrices developed for this project provide some limited insight for suggesting possible changes to the organizational structure. Unfortunately, the high-level nature of the enterprise model analysis significantly limits the ability to draw extensive conclusions from the results.

C. RECOMMENDATIONS FOR THE COMMITTEE ON NPS MISSION ORGANIZATION STUDY

The timing of this project report coincides with an effort by the Provost/Academic Dean to determine whether or not structural changes are required for the NPS organization. The Committee on NPS Mission Organization has a charter and a list of questions, shown in Figure IV.15, to guide their effort.

The NPS enterprise model analysis suggests answers to some of these questions proposed by the Provost. The analysis and

LIST OF QUESTIONS FOR COMMITTEE ON NPS MISSION ORGANIZATION

1. Does the Office of the Dean of Faculty have too much administrative oversight for a single individual? Should NPS return to Divisional Deans? If so, define the Divisions.

2. Do the functions of the Office of the Dean of Faculty overlap too strongly the functions of the Office of the Dean of Instruction? Do we need both offices? How do we define the functions?

3. Do the functions of the Office of Dean of Students/Director of Programs overlap too much those of the Dean of Instruction? If these are to be retained, how should one divide the respective functions?

4. Do we need a Dean of Research or is an Office of Research Administration adequate?

5. Should the concept that NPS really operates a matrix organization be expanded or more formalized. this suggests that 07 and 08 develop faculty and faculty research sources, whereas 03 and 06 support curricular, instructional, and student activities.

6. Is the combination of Computer Services and Information Services appropriate? Or should they be split and put under the supervision of other Deans or answer directly to the Provost? How does one divide the computing responsibilities between this organization and the individual Departments?

7. Has the function of part-time Associate Deans served NPS well in identifying and giving administrative experience to a wider group of young faculty, or has it produced too much administration? How best can NPS accomplish these functions?

8. The position of Assistant to the Provost has expanded its functions over time to include: 1) a budget office for faculty, staff, and OPTAR mission budgeting; 2) a staff administrative office to reduce the burdens of administering the staff by the respective Deans and Chairs; 3) an Office of Institutional Research to centralize institutional data, its collection, and its organization. Are these appropriate? What changes are recommended?

9. Who should have responsibility for development and marketing of new instructional programs? new research centers? new instructional laboratories? distance learning? the international programs?

10. In recommending changes, seek ways to reduce the administrative overhead of the institution.

Figure IV.15 List of Questions for NPS Mission Organization (NPS-01, August 16, 1994)

recommendations that follow address their respective numbered questions from Figure IV.15:

Question #2. The functions of the Dean of Faculty overlap the functions of the Dean of Instruction, particularly in

educational program planning, conduct, and administration; faculty selection, orientation, and development; appointment of Academic Associates; supervision of Academic Associates; and curricular reviews. The Function vs. Organizational Unit Matrix (Tab C of Appendix D) shows that both Deans have "Direct Management Responsibility" for the same function -- *Provide Instruction to Students.* Review of the Code 06 and Code 07 functions in the Activity Hierarchy Decomposition (Tabs M and N of Appendix D) provides additional examples of this functional overlap. Both offices conduct functions which are unique and should remain distinctly separate; only the overlapping functions should be divided between the two offices. The Dean of Faculty can deal with personnel issues, such as faculty selection, orientation and development and the appointment and supervision of Academic Associates. The Dean of Instruction can deal with academic issues, such as educational program planning, conduct and administration and curricular reviews.

Question #3. The functions of the Dean of Instruction significantly overlap the functions of the Dean of Students/Director of Programs, especially in the areas of curricular program planning, evaluation, and development; curricular reviews; and military faculty selection, orientation, and development. As in the previous question, the Function vs. Organizational Unit Matrix (Tab C of Appendix D) shows a significant overlap in "Direct Management

Responsibility" between Code 03 and Code 07 in almost all functional areas. This overlap also shows up in the Activity Hierarchy Decomposition (Tabs M and N of Appendix D). The Dean of Students/Director of Programs currently serves as the coordinator for the military aspects of each curricular program, such as the military educational requirements (MER). This function goes better with the Office of the Dean of Instruction, who coordinates the academic aspects of each curricular program. Curricular reviews and faculty selection also go better with the Dean of Instruction.

Question #4. Due to the importance research plays in the accomplishment of the NPS mission, a Dean of Research is appropriate. A Dean of Research serves as the single focal point for this important function; his duties and responsibilities go far beyond simply supervising the administration of the paperwork. The Function vs. Organizational Unit Matrix (Tab C of Appendix D) and the Activity Hierarchy Diagram Decomposition (Tabs M and N of Appendix D) show the extent of the Dean's duties and responsibilities.

Question #5. As discussed in the previous paragraphs, the overlapping responsibility for functions in the matrix organization at NPS hinders effectiveness and efficiency. When the Dean of Faculty concentrates on faculty members, the Dean of Research concentrates on research, the Dean of Instruction concentrates on curricula instruction, and the

Dean of Students concentrates on military student administration, the effectiveness of the organization increases as the amount of interdepartmental coordination for specific activities is reduced.

Question #6. A proposed solution is a central organization combining the functions of Computer Services and Information Services, headed by a professional, experienced Corporate Information Officer reporting directly to the Superintendent. The central organization responsibilities include all common infrastructure issues, such as the campus backbone, network connectivity, campus-wide e-mail, life-cycle management, software licensing and configuration management, data standardization, and long-range strategic planning. Every department/code provides operation and maintenance for their specific systems, coordinated through the central organization, which has divisions for academic, research, administrative, library, and infrastructure information systems.

Question #8. The functions performed by the Assistant to the Provost duplicate the functions performed (or assigned) to numerous other organizational codes at NPS. The Function vs. Organizational Unit Matrix (Tab C of Appendix D) clearly shows the overlap in "Direct Management Responsibility" between the Provost's Academic Planning Code 011 and the Dean of Faculty. The Activity Hierarchy Diagram Decomposition (Tabs M and N of Appendix D) also detail this functional duplication. The

budget office functions duplicate functions assigned to and performed by the Director of Resource Management and his staff. The staff administrative office functions duplicate or supplement the efforts of the other Deans' staffs; if all that is required is additional staff for surge support, a rotating staff pool would suffice. The functions performed by the Office of Institutional Research directly conflict with the responsibilities of the Dean of Computer and Information Services and his staff, especially the position of Director of Management Information Systems. This last conflict may be unseen due to the prolonged vacancy in the MIS Director position. Restoration of all these functions to their assigned codes has the potential to significantly reduce the amount of duplicative and unproductive effort; key to this shift of responsibilities is the improvement of management information access for the Provost/Academic Dean.

Question #9. Based on the previous answers, the responsibilities addressed in this question belong to: The Dean of Instruction for new instructional programs; the Dean of research for new research centers; the Dean of Instruction for new instructional laboratories; the Dean of Computer and Information Services for distance learning facilities; the Director of Programs for international programs.

D. RESOURCE CONSTRAINTS

Although a discussion of resource constraints is a little out of place in this chapter, due to the focus on the NPS enterprise information architecture, this chapter provides the logical venue for this continuation of the analysis of the NPS enterprise. The resource constraints of interest consist of financial constraints and personnel constraints, as discussed below.

1. Financial Constraints

Implementation of any data management architecture requires funding for many items related to the underlying technical infrastructure: purchase of new or upgrade to existing hardware, purchase of new or upgrade to existing software, purchase of new or upgrade of existing peripherals, hiring new IS personnel, training new and existing IS personnel, training new and existing users, conversion of data in existing databases, and so on. The entire NPS enterprise bears these costs for an enterprise-wide architecture implementation, not just a single department or organizational unit. Therefore, this type of infrastructure implementation impacts all sources of funding, including military appropriations and academic department reimbursable funds.

Determination of the total IS budget at NPS is a difficult task, due to the multiple sources of funds, including multiple appropriations (O&M,N and OPN) and multiple

funds from specific reimbursable research activities. Additionally, the IS budget funds many categories of costs, including hardware, software, peripherals, maintenance contracts, training, and personnel wages and salaries. An estimate of the fiscal year 1994 IS budget is approximately $9M, with approximately $5M from appropriated funds and the remainder from reimbursable funds.(FLDSUPPACT, 1994; ASDP, 1994)

Review of the individual 1994 Abbreviated System Decision Papers (ASDPs) submitted by the academic departments and organizational codes in lieu of an IS/IT budget reveals this total amount is budgeted to support the initiatives, within each academic department and organizational code, for the development of new or upgraded information systems, or to provide maintenance for existing systems in addition to the new systems. (Chapter VI provides additional details in Table VI.14.) No spare funding exists for the implementation of an enterprise-wide data management architecture without impacting all organizational units and their individual acquisition plans. Implementation delay is therefore inevitable due to the lack of immediately available funding and the need to plan and program the data management architecture implementation into the budget out-years.

2. Personnel Constraints

The key issue with respect to personnel constraints is the availability of experienced personnel to support the transition and operation of a new data management architecture and its underlying technical infrastructure. Either existing personnel have the requisite training and experience, and exist in sufficient numbers to support the increased data management tasks, or NPS must hire additional personnel.

Review of multiple documents provided by the NPS Code 05 organization outlining the NPS mission staff, both within the Code 05 organization and throughout the entire school provides an overview of the information system support personnel at NPS. A memorandum on "Support and Research Staff Levels" (Lewis, 1994) identifies 101 total civilian computer system support personnel at NPS, distributed throughout 21 organizational codes or academic departments. The memorandum also provides a partial breakdown of personnel skills and experience levels in the three largest personnel groups. A listing (HRO, 1994) of the personnel assigned to the Computer and Information Services Code (Code 05) reveals numerous authorized positions are vacant, ranging from the Dean of Computer and Information Services (currently filled by the Provost/Academic Dean as the Acting Dean), the Director of Academic Computing (also filled by an Acting Director), the Director of Management Information Services, to numerous other supervisory and technical positions. As of the 05 May 1994

date of the report, a total of 15 positions in the Code 05 organizations are vacant. Vacancies also exist in the other academic departments and organization codes.

The high number of vacant key personnel positions, and thus a corresponding lack of technical information skills and expertise throughout the NPS enterprise, effectively prevents implementation of any new data management architecture at NPS without also hiring more personnel. Data management is a problem now; the data management requirements for any other data architecture are even more stringent and demanding. NPS must hire and train sufficient personnel to support the increased demands of a new data architecture and its underlying technical infrastructure.

E. CHAPTER SUMMARY

This chapter provides an overview top-level analysis of the Naval Postgraduate School and its information architecture. The analysis develops a high-level data model, an activity or function model, and supporting documentation. The analysis includes a discussion of several questions posed by the Provost/Academic Dean to a Committee on NPS Mission Organization, and a review of the financial and personnel resource constraints.

The following chapter provides a discussion of the alternative data management architectures and technologies that are currently available for implementation at NPS.

V. DATA MANAGEMENT ARCHITECTURE ALTERNATIVES

This chapter provides a discussion of the different types of data management architectures analyzed for possible use by the Naval Postgraduate School enterprise, and addresses the underlying technical infrastructure architecture issue.

A. DATA MANAGEMENT ARCHITECTURE ALTERNATIVES

The design of any data management architecture is highly dependent on the underlying technical infrastructure, which defines the type of processing in the environment. Therefore, any discussion of data management architecture alternatives first requires a discussion of the different forms of technical infrastructure architectures.

1. Technical Infrastructure Architectures

The structure of any technical architecture generally involves some form of distributed or "cooperative" processing, except in the isolated case of a system consisting solely of stand-alone personal computers (PC). *Distributed processing* consists of multiple interconnected processors operating at the same time. *Cooperative processing* is simply a subset of distributed processing; whereas the goal of distributed processing is to move the processing as close to the user as possible, the goal of cooperative processing is to move the processing to whichever component is best suited for the job

(Sprague and McNurlin, 1993, p. 147). Another name for distributed or cooperative processing is *peer-to-peer processing*, based on the roles of the processors. Peer-to-peer processing contrasts with the concept of client/server processing. *Client/server processing* is simply a subset of distributed or cooperative processing, wherein one processor generally serves as a "client", making requests to a "server" processor. Most descriptions of client/server processing categorize five specific types, varying in functionality and complexity, based on the division of services between the host (also known as the server) and the desktop computer (also known as the client). These categories apply equally to the larger superset of distributed or cooperative processing systems as well. Tony Percy (1994) defines these five categories as:

1. Distributed Presentation
2. Remote Presentation
3. Distributed Function
4. Remote Data Management
5. Distributed Database

Figure V.1 provides a graphical representation of the service division between the host and the desktop computers for each of these five categories.

In *distributed presentation*, the desktop computer (client) and the host computer (server) share the presentation duties, i.e., the desktop computer typically provides a

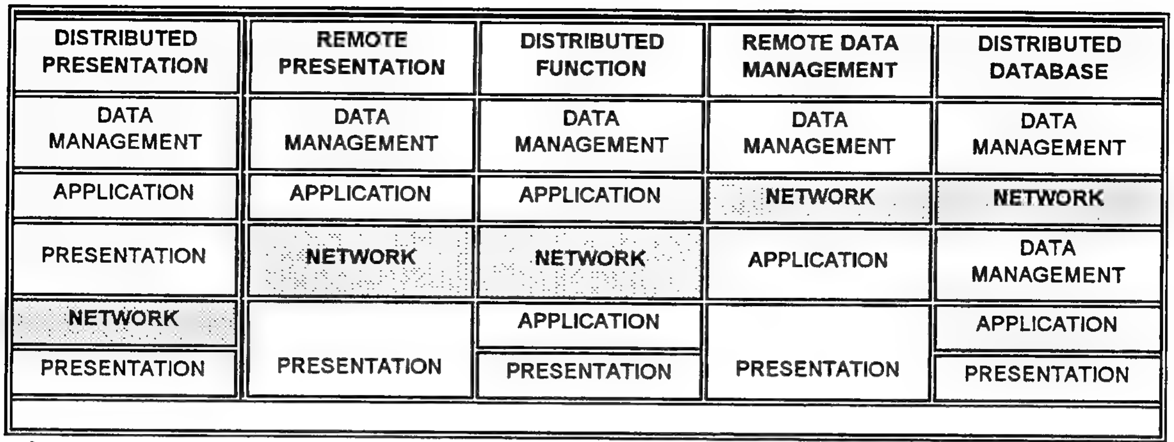

Figure V.1 Cooperative Client/Server Processing (Percy, 1994)

graphical user interface for a more "user-friendly" display and interaction. Another name for the new user interface is "frontware"; the interaction is also called "screen scraping".

In *remote presentation*, the desktop computer provides all the interface functions through messages to/from an application that is running solely on the host computer. This approach allows multiple front-ends access to the same application. (This is also known as server-driven client/server processing.)

In *distributed function*, the desktop computer and the host computer share the application duties, i.e., the application running on the desktop submits queries in the form of remote procedure calls (RPC) to the host computer, where standard services accomplish the request.

In *remote data management*, the desktop computer contains the application and accesses the data stored on the host computer when required. Typically a Data Base Management

System (DBMS) installed on the host provides all data management. Any preliminary data processing, such as sorting, is accomplished on the host computer based on the commands (usually in the form of Structured Query Language (SQL) statements) sent by the desktop computer; only the resultant data is returned to the desktop computer. (This is also known as client-driven client/server processing.)

In *distributed database*, the DBMS controls how the desktop computer and the host computer share the data management duties, i.e., the desktop computer may download a portion of the host's data base to the desktop, and locally perform various data functions such as sorting and report generation; the host computer may perform the processor intensive duties such as the initial data base query and preliminary sorting.

Many different forms of distributed or cooperative processing systems exist, including:

1. A system consisting of a mainframe host and user terminals.
2. A system consisting of multiple PCs or workstations connected in a Local Area Network (LAN), with or without dedicated servers.
3. A system consisting of a mainframe host and multiple PCs or workstations connected in a Local Area Network (LAN), with or without other dedicated servers.
4. A system consisting of multiple mainframe hosts, PCs, workstations, and/or LANs connected in a Metropolitan Area Network (MAN) or a Wide Area Network (WAN).

The evolution of distributed processing systems follows two converging paths: the evolution from mainframe hosts and terminals to mainframe hosts and workstations (or PCs) and the evolution from stand-alone PCs to networked PCs (or workstations). Figure V.2 graphically portrays this evolution of distributed processing. An advanced form of distributed processing is a system that allows multiple different machines using different operating systems on different types of networks to cooperate on the same task.

The trend in information system technology today is toward more distributed processing, especially in the area of distributed databases. The impetus behind this trend is twofold; organizations want to move responsibility for computing resources closer to the actual users, and they want to improve the use of computer resources.

Robert Murray (1991, pp. 61-64) defines eight phases in the migration path to fully distributed processing systems:

1. Host-based, real-time query and update.
2. Host-based, real-time query and update with additional query through file transfers to PCs.
3. Host-based, real-time query and update with additional query through file transfers to PCs and batch updating permitted from PC data.
4. Real-time query and update from either host or PC.
5. Homogeneous cooperative processing without two-phase commit, where like databases run on the same hardware and system software platforms.
6. Heterogeneous cooperative processing without two-phase commit, where databases run on a mix of platforms.

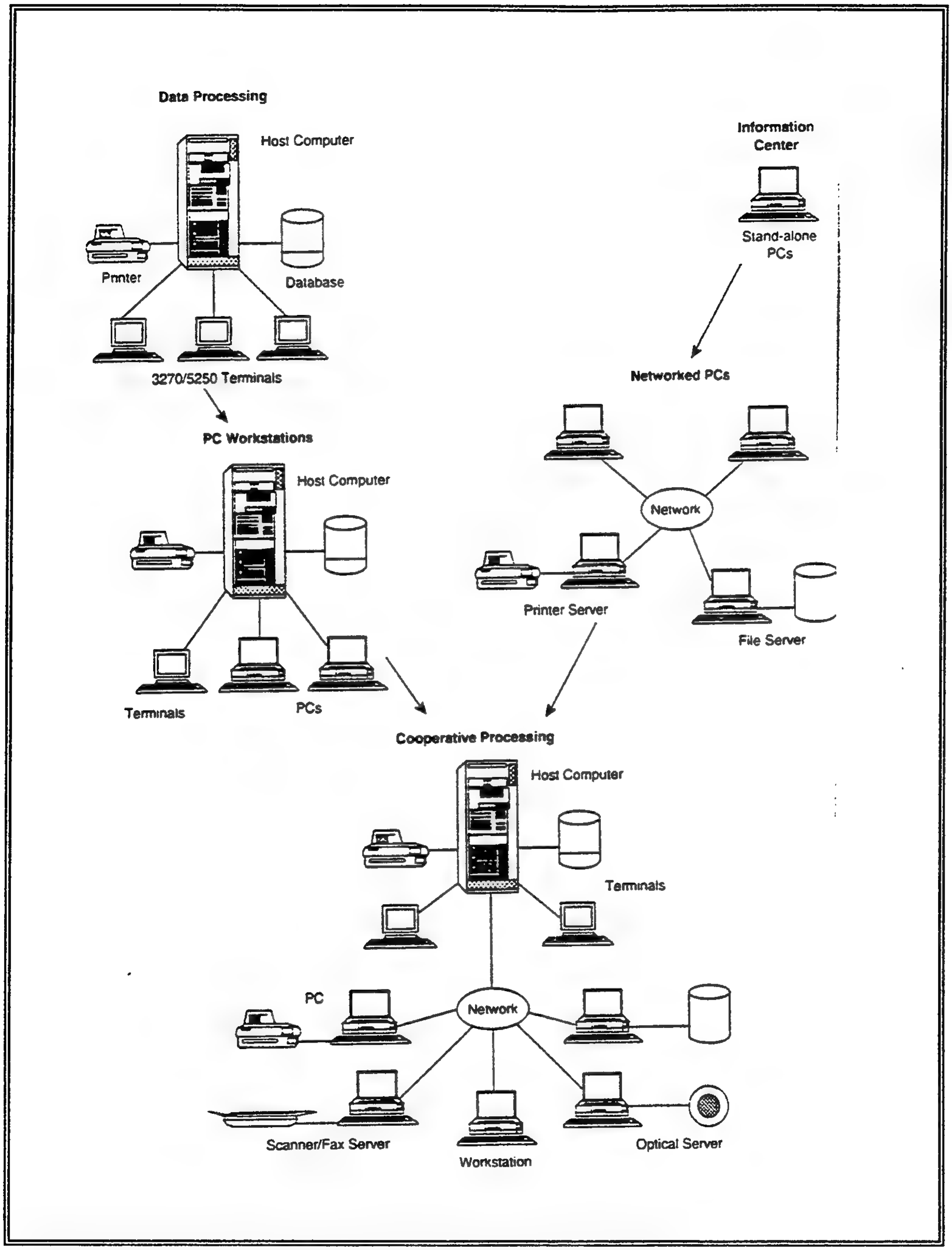

Figure V.2 Cooperative Processing Evolution
(Sprague and McNurlin, 1993, p. 146)

7. Homogeneous cooperative processing with two-phase commit.

8. Heterogeneous cooperative computing with two-phase commit.

Phase one is the traditional on-line information system processing. Phase two extends the traditional host-based applications to allow PCs to download portions of a database for use in local applications; however, no capability exists to update the host database. Phase three adds batch update capability from a PC. Now the host acts as a "back-end" database server and processor, and the PC acts as the "front-end" to manipulate and update the local data. Phase four simply extends the capabilities of the PC to allow on-line vice batch updates to the host database. Phase five distributes databases across similar or identical platforms, but without a *two-phase commit* capability.[7] Phase six simply extends phase five to multiple types of platforms, still without two-phase commit capability. Phase seven adds the two-phase commit capability, providing a true distributed database. Phase eight simply extends the previous phase to heterogeneous databases on mixed hardware platforms. (Sprague and McNurlin, 1993, pp. 166-167)

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[7] *Two-phase commit* is a method to ensure data integrity; the method uses a two-step process to lock and update all duplicate copies of data before any of the affected databases are committed to the update. If any of the updates fail, the transaction is not completed, i.e., backed out. (Sprague and McNurlin, 1993, p. 167)

2. Data Management Architectures

The system's data storage design typically drives the structure of the system's data management architecture. Sprague and McNurlin (1993, p. 213-219) identify several different types of data storage approaches:

1. Downloaded Data Files
2. Multiple Stored Copies of Data
3. Unsynchronized Distributed Databases
4. "True" Distributed Databases
5. Client/Server Databases
6. Federated Databases

Discussions of each of these approaches is provided in the following sections.

a. Downloaded Data Files

Downloading data from a mainframe (or minicomputer or server) is one of the most common data distribution methods in use today. This resource-sharing approach covers a wide range of options, including: distribution of reports, download of selected data files, and even (rarely) updates of data files to the host. The most prevalent uses for this type of architecture are query and reporting from downloaded data. Figures V.3 and V.4 provide a graphical depiction of this data management architecture.

Four potential problems with downloading data are coordination, consistency, access control, and computer crime.

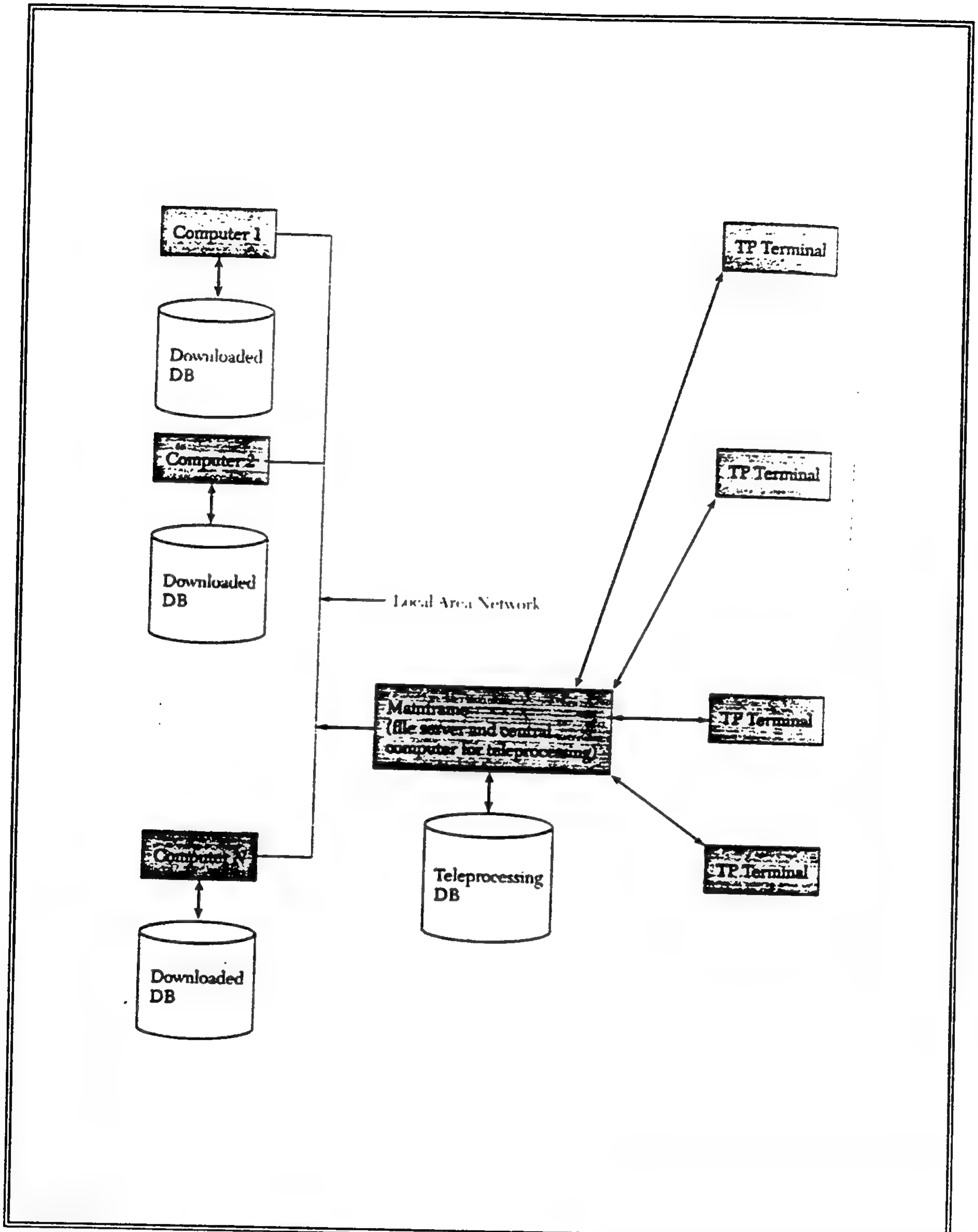

Figure V.3 Resource Sharing of Downloaded Data
(Mainframe as server)
(Kroenke, 1992, p. 524)

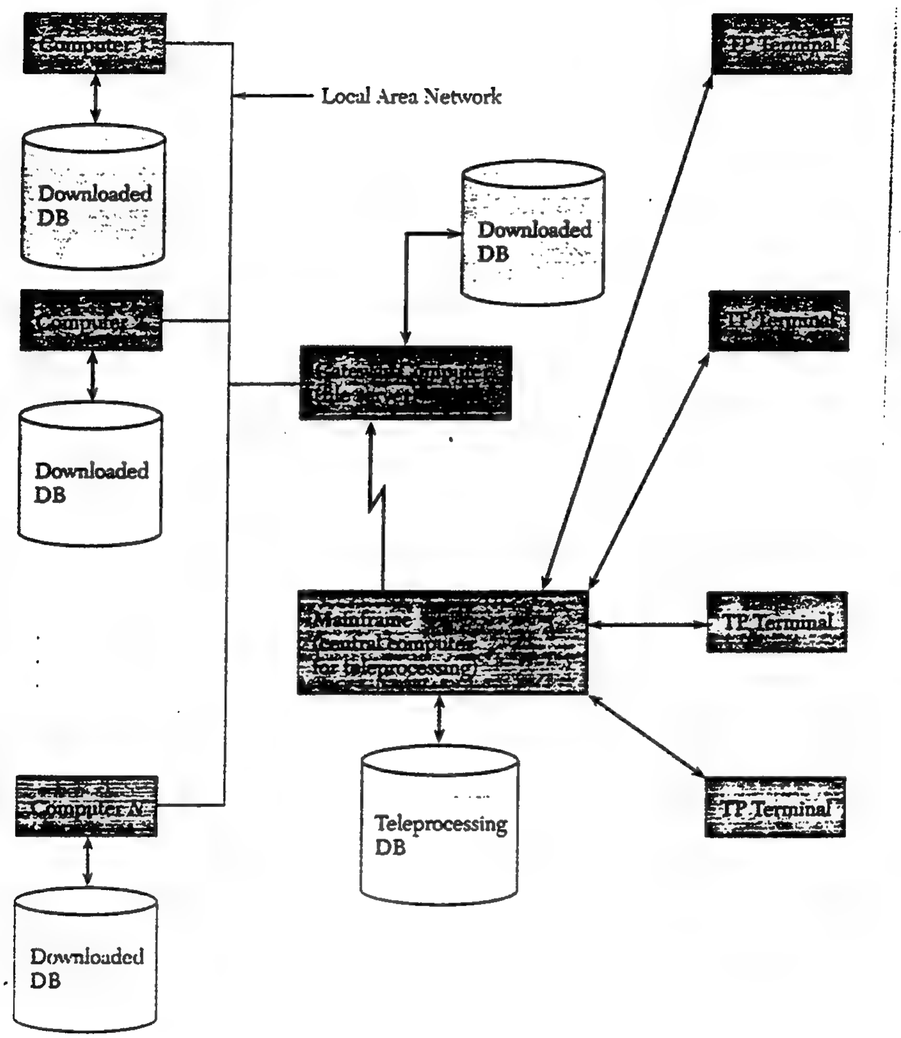

Figure V.4 Resource Sharing of Downloaded Data (gateway microcomputer as server) (Kroenke, 1992, p. 525)

Coordination refers to coordination of database management actions between the client computer and the server computer. *Consistency* refers to control over local updates to downloaded data. *Access control* refers to protecting against inappropriate but legal behavior; *computer crime* refers to illegal behavior, such as data theft. (Kroenke, 1992, p. 528)

Sometimes the data distribution is indirect, through the use of an "extract" file or other information database; the data is then downloaded from the intermediate database by the users. Data warehouses are a special purpose form of an information database, and their conceptual use is sufficiently important to warrant separate discussion in a later section of this chapter.

b. Multiple Stored Copies of Data

Multiple specified locations (servers) store duplicate copies of the databases (through a process known as "replication"), and make them accessible to the users for processing queries and updates. Infrequent but periodic updates occur to the centrally maintained databases, usually through a formally controlled batch process after working hours; after updating, the central databases download the updates to all the remote locations. Lack of data integrity at the remote locations between updates is an obvious

shortcoming of this approach, but it is generally not a critical issue for those organizations which choose to implement this method.

c. *Unsynchronized Distributed Databases*

The use of unsynchronized distributed databases is similar to the use of multiple stored copies of data, since in both cases the databases update relatively infrequently but at periodic intervals. The difference lies in the timing of the updates; in unsynchronized distributed databases the secondary copy of the distributed database typically updates itself more frequently, at regular periodic intervals or triggered by some event, as opposed to once in any given day. This approach provides a mechanism for improved data access performance when data integrity is not a critical issue, and the error can be caught quickly and fixed easily.

Several large database vendors have commercial implementations of this type of data management architecture, using different types of database replication. Some replication engines allow data to be updated at regular timed intervals; others provide replication based on trigger events, such as an update. Still others operate continuously, using a store-and-forward mechanism to update secondary databases with primary data whenever updates occur. Store-and-forward replication also provides a mechanism to rapidly recover from

a secondary site failure. Figure V.5 provides a graphical depiction of some of the replication mechanisms.

Generally, all replication mechanisms use two-phase commit methods to ensure data integrity; but the implementations vary between vendors. Some vendors use two-phase commit for each and every replication, thereby ensuring that all copies of the data are 100 per cent consistent at all times. Other vendors define a primary copy for every piece of data, which gets updated first using two-phase commit procedures, and then replicates the data to all the secondary sites asynchronously and independently; although this may result in a data integrity issue between copies, in most cases the total replica distribution occurs in seconds. (Baum, 1994a; Skrinde, 1994)

d. "True" Distributed Databases

Two definitions exist for true distributed databases; the first definition consists of a distributed, non-duplicated database and the second consists of distributed duplicate copies of the database. Figure V.6 provides examples of these and other types of distributed databases. In a database that has been partitioned and distributed throughout a system without duplication, any portion of the database is accessible from any processing node (subject to access control). Applications (and users) need not know where a particular portion of data resides -- the system keeps track

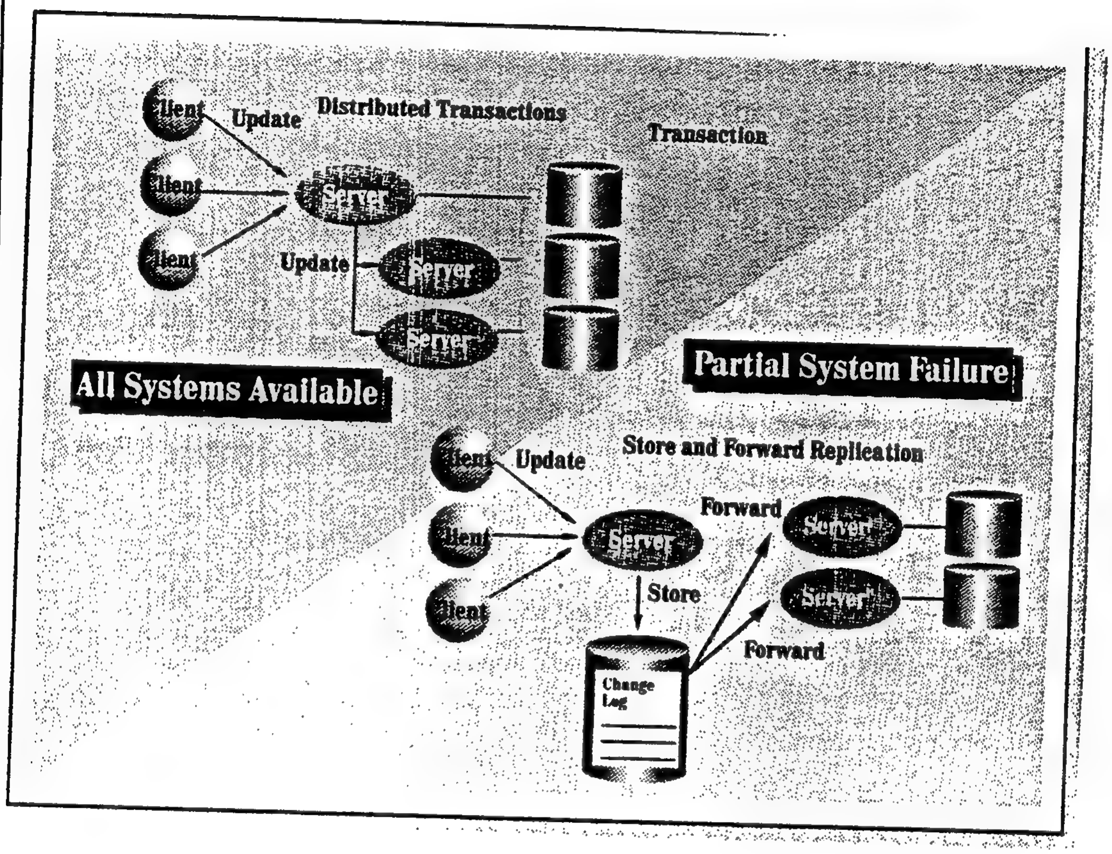

Figure V.5 Distributed Database Replication Modes (Skrinde, 1994)

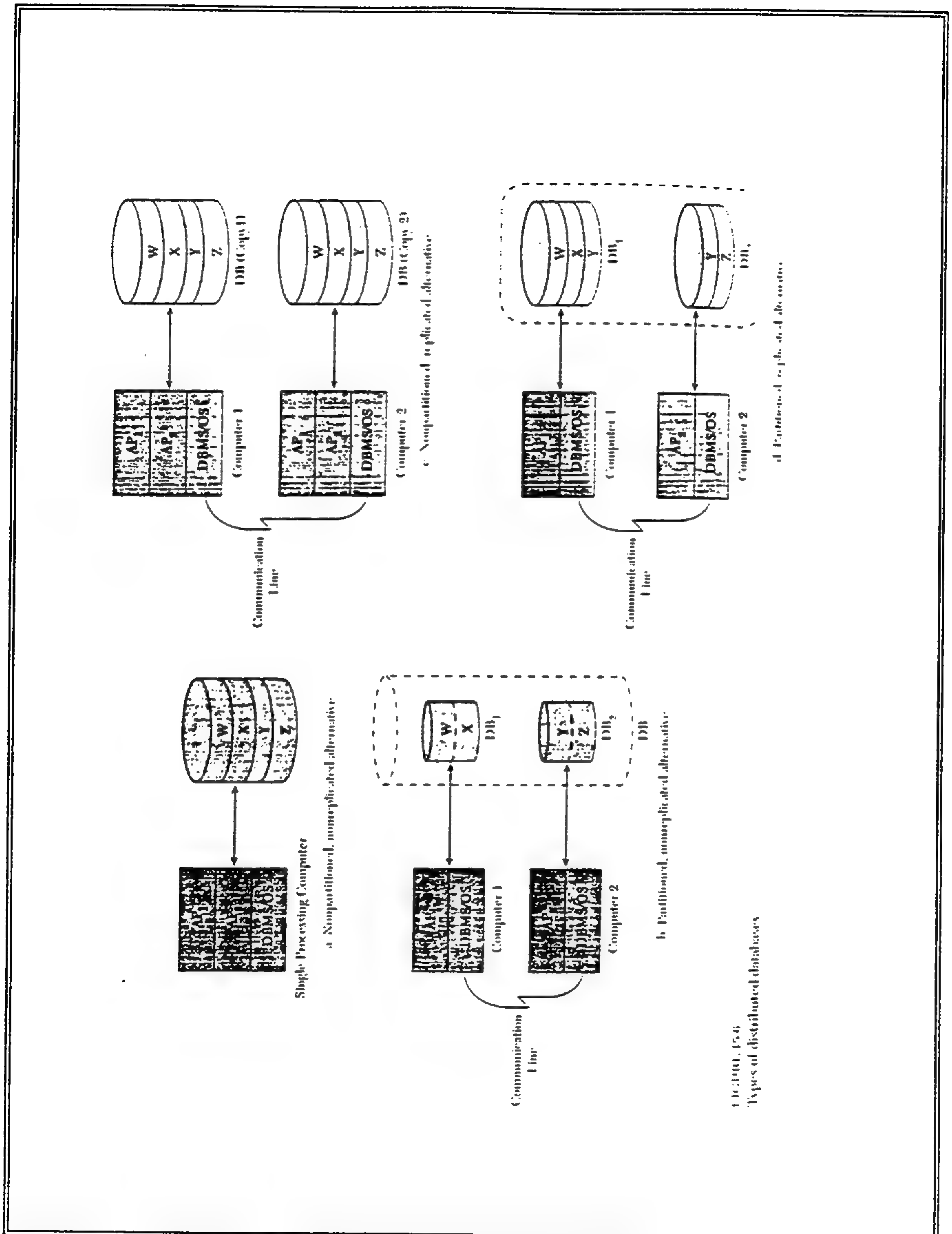

Figure V.6 Types of Distributed Databases
(Kroenke, 1993, p. 522)

of that transparently. In a database that has been duplicated (replicated) and distributed throughout a system, the same data resides at each location. Again, applications (and users) need not know where a particular portion of data resides, since they have access to all the data at any location. However, data synchronization to maintain data integrity is a significant problem in this approach.

The definitive operating principles for the distributed database field are the definitions contained in Chris Date's (1987) twelve rules for a distributed database and Michael Stonebraker's (1986) seven kinds of transparency. The twelve rules are listed in Figure V.7 and the seven types of transparency are listed in Figure V.8. Implicit in these distributed database operating principles is the requirement that the underlying databases be relational databases.

Sprague and McNurlin (1993, p. 216) declare that the three biggest challenges facing the designers of true distributed systems are: choosing a standard data access language, synchronizing distributed databases, and optimizing queries. The current standard data access language is SQL. (SQL is discussed in greater detail in Appendix E, Middleware.) Synchronizing distributed databases requires implementation of the two-phase commit (or similar) methodology, preferably at the databases and not in the applications. Optimizing queries requires an intelligent query optimizer that can rapidly analyze changing system

1. **Local autonomy.** Local data is owned and managed locally, with local accountability and security. No site depends on another for successful functioning.

2. **No reliance on a central site.** All sites are equal, and none relies on a master site for processing or communications.

3. **Continuous operation.** Installations at one site do not affect operations at another. There should never be a need for a planned shutdown. Adding or deleting installations should not affect existing programs or activities. Likewise, portions of databases should be able to be created and destroyed without stopping any component.

4. **Location independence** (transparency). Users do not have to know where data is physically stored. They act as if all data is stored locally.

5. **Fragmentation independence** (transparency). Relations between data elements can be fragmented for physical storage, but users are able to act as if the data was not fragmented.

6. **Replication independence.** Relations and fragments can be represented at the physical level by multiple, distinct, stored copies or replicas at distinct sites, transparent to the user.

7. **Distributed query processing.** Local computer and input/output activity occurs at multiple sites, with data communications between the sites. Both local and global optimization of query processing are supported. That is, the system finds the cheapest way to answer a query that involves accessing several databases.

8. **Distributed transaction management.** Single transactions are able to execute code at multiple sites, causing updates at multiple sites.

9. **Hardware independence.** Distributed database systems are able to run on different kinds of hardware with all machines participating as equal partners where appropriate.

10. **Operating system independence.** Distributed database systems are able to run under different operating systems.

11. **Network independence.** Distributed database systems are able to work with different communications networks.

12. **Database independence.** Distributed database systems are able to be built of different kinds of databases, provided they have the same interfaces.

Figure V.7 Twelve Rules for Distributed Databases (Sprague and McNurlin, 1993, p. 214)

conditions to determine the fastest and most efficient steps to handle the query.

1. **Location transparency.** A user can submit a query that accesses distributed objects without having to know where the objects are.

2. **Performance transparency.** A distributed query optimizer finds the best plan for executing a distributed command, which means that a query can be submitted from any node in a distributed database and it will run with comparable performance.

3. **Copy transparency.** The system supports the optional existence of multiple copies of database objects.

4. **Transaction transparency.** A user can run a transaction that updates data at a number of sites. It behaves exactly like a local one, with the ultimate effect being that it either commits or aborts; no intermediate states are possible.

5. **Fragment transparency.** The distributed DBMS allows a user to cut up a relation into multiple pieces and place them at multiple sites according to certain distribution criteria.

6. **Schema change transparency.** Users who add or delete a database object from a distributed database only need make the change once to the distributed dictionary. They do not need to change the catalogs at all sites that participate in the distributed database.

7. **Local DBMS transparency.** The distributed database system is able to provide its services without regard for the local DBMSs that are actually managing local data.

Figure V.8 Seven Types of Transparency
(Sprague and McNurlin, 1993, p. 215)

e. Client/Server Databases

Client/server databases are very similar to true distributed databases, with one significant exception. The difference involves the concept of location independence or transparency; client/server databases do not support the

concept of location transparency. In a client/server environment, the DBMS only runs at selected locations; therefore the applications (users) must know where the DBMS is located to be able to access the data. Numerous client/server databases operate in organizations throughout the world today.

The different forms of client/server processing are the five types illustrated in Figure V.1, and need not be repeated here. The resources immediately at hand typically drive the decisions on how to distribute processing among clients and servers. For many organizations, the historical "legacy" data is stored on a mainframe computer. No strategy for migration to a client/server technology can ignore this data, and its accessibility. One way for an organization to make their legacy data available, and also preserve a large hardware/software investment, is to make the organizational mainframe computer a server.

(1) Mainframe as Server. With the advances in computer technology, and the increases in processing power available in smaller units, mainframes are no longer accessed primarily for their processing power, but for the information that resides there. Therefore, the mainframe can act as a master server in an enterprise network, aided by other intelligent servers acting as clients to the mainframe server. Unfortunately, due to the incompatibilities of hardware,

system software, database structures, and application programs, a mainframe has limits on the role as a server.

Several approaches exist for a mainframe in the server role: a LAN file or printer server, a database query server, and an application server. Mainframes have tremendous disk storage capacities and fast laser printers for bulk printing jobs. IBM and other mainframe vendors provide numerous products to support the mainframe's use as servers. A sampling from IBM's list includes: LAN Resource Extension and Services, which provide disk serving, data distribution, LAN to host printing, host to LAN printing, and LAN administration; Workstation LAN File Services, which provides a fast, large-scale file server; the Data Facility Distributed Storage Manager, which supports multiple vendor hardware client platforms; and support for a wide range of network connectivity options. Client/server file sharing using a mainframe generally requires the mainframe to emulate every database action, which is woefully inefficient. However, use of a mainframe as a SQL-based query server provides significant processing power when required for querying large databases. Justifying the use of a mainframe as an application server requires either a pre-existing mainframe database or a large user population uniquely supported by the mainframe. Two example areas where mainframes generally fulfill these criteria is in office-system support and imaging systems.

A mainframe requires several architectural changes to improve its role as a server. These changes include: greater on-line disk capacity, and improved seek performance in disk systems. The improved seek performance results from drive enhancements, disk drive head queuing, use of Redundant Arrays of Independent Disks (RAID) in a "disk striping" mode, and caching. Other improvements include mechanisms to improve interconnectivity, such as communications gateways and other LAN connections. Finally, the mainframe requires improved vendor support for several systems management issues, including software distribution, database reconciliation, and remote operation and administration. (Nolle, 1994; Salemi, 1993)

f. Federated Databases

The author defines a federated database system as a system that uses autonomous heterogeneous databases. Frequently (but not always) the databases store incompatible data types, such as text, audio, video, images; use of a federated database system avoids the problems associated with storing all the different data types in one single database. The application consolidates the data from each separate type of database and displays it in whatever format is required. Federated database systems require data access tools (middleware) to retrieve the mixed format data from

heterogeneous databases on mixed platforms. Appendix E discusses data access methods and middleware.

3. Data Warehouses

As previously mentioned, data warehouses are a form of information database. Although industry uses the term data warehouse for numerous concepts, the three most prevalent are: an aggregated information database based on extracted operational data structured to support Decision Support Systems (DSS) and Executive Information Systems (EIS), an enterprise data bus, and an all-source information database, containing operational, external, and other internal data.

The primary data warehouse concept arises from a need for a better method of gathering and maintaining decision support data, or the desire to gain informational access as opposed to operational access to corporate data. Operational access is access to the current state of specific data instances; informational access applies to large volumes of corporate data for higher level assessment, planning, and strategic decision-support activities. Two environmental conditions drive this need. First, the operational transaction processing environment provides no historical perspective for use in decision-making. Second, operational data is not easily accessible to decision makers -- someone must first locate and extract the appropriate data, verify it, summarize it, integrate it with data from other sources,

organize it for a specific purpose, and then move it into a database where it can be easily and uniformly accessed by the managers who need it. A requirement to repeat the entire process every time an analysis is performed proves this approach is inefficient and expensive. Industry's proposed evolutionary solution is the data warehouse:

> The data warehouse provides the architecture to model, map, filter, integrate, condense, and transform data into meaningful information that can be accessed, analyzed, and acted upon. It keeps track of the data's source and its target table within the database, with a time stamp to ensure that users compare apples to apples. (Ashbrook, 1993)

Operational data is filtered based on predetermined user selection criteria, summarized over a time horizon, and further focused and integrated with other data as it moves into the data warehouse. Figure V.9 provides a graphical view of a data warehouse architecture. (Ashbrook, 1993; Inmon, 1994; Red Brick, 1993; Ferrara and Naecker, 1993)

An organization's evolution to data warehousing has three basic stages: application access, the information center, and the data warehouse. Application access implies that informational access is obtained by users through a request to the IS department for another report against an operational production database. This stage further evolves as end-user data access tools proliferate, and the IS department is removed as a bottleneck. The second stage, information center, is really a small-scale (i.e., departmental) data warehouse, where data from one or more

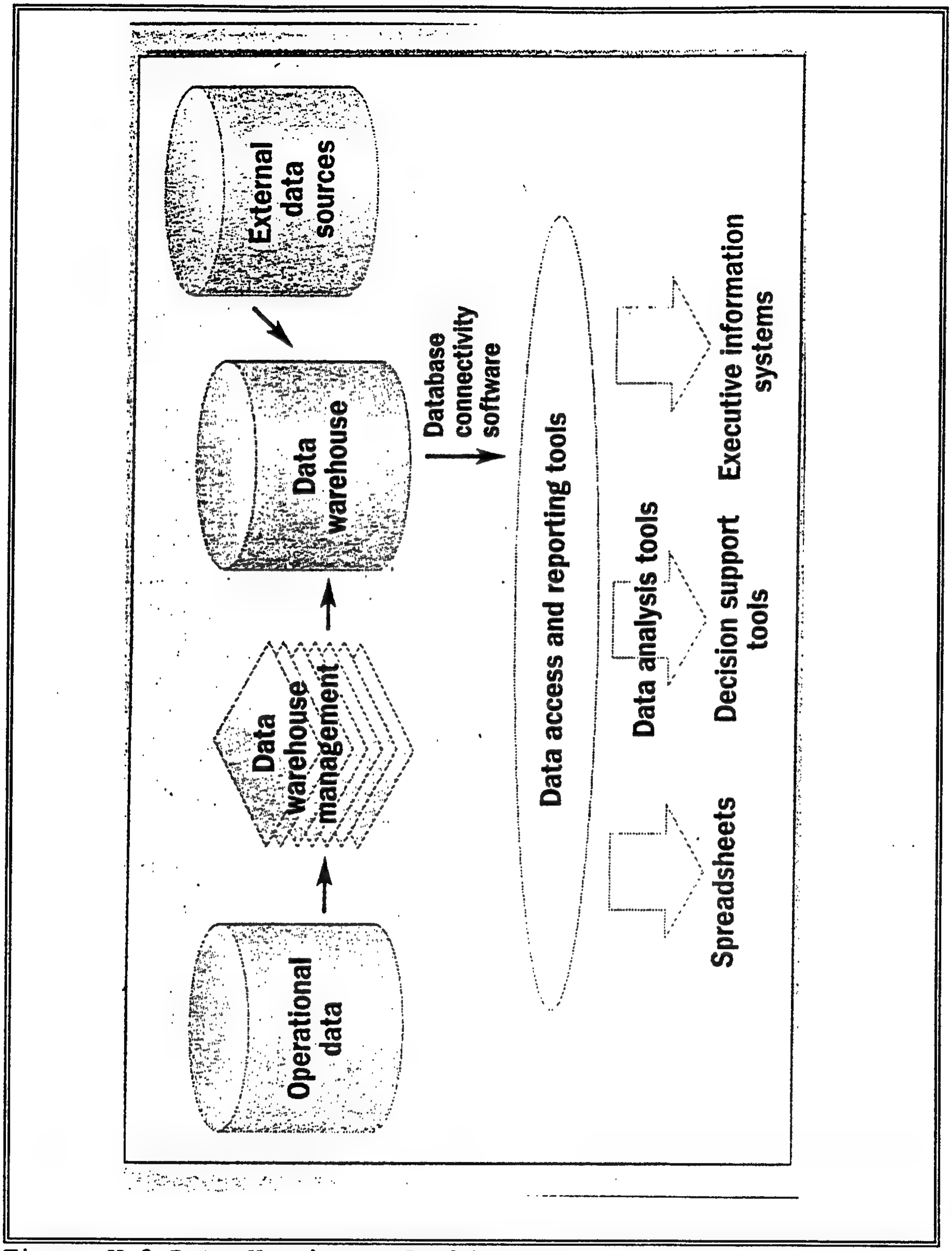

Figure V.9 Data Warehouse Architecture
(Wallace, 1994)

operational systems is extracted into an information database. Because the information center database is separate from the operational data, database structure and data element definition standardization can take place, simplifying end-user access. Some industry analysts champion the information center "datamart" idea as a more useful and affordable resource than a data warehouse, based on an assumption that only a subset of the corporate data is relevant to a particular group of users (Wallace, 1994). This stage evolves to a condition where multiple information centers exist, each addressing a different type of need. The next stage is the data warehouse. The key difference between the data warehouse and the information center is scope. A data warehouse is a fully architected, enterprise-wide informational access environment. (Ferrara and Naecker, 1993)

Another perspective on the evolution of the data warehouse is provided by Colin White (1993). White defines four approaches along the evolutionary path leading to data warehousing. In the first approach business users apply host-based decision support tools against a centralized operational database. This is a traditional approach for providing end users with access to corporate data. A significant amount of this type of processing uses batch-oriented report and data-analysis programs that access and process file and non-relational database data (legacy data), although newer tools also access relational databases. The second approach

provides business users with workstation-based decision support tools that access centralized enterprise-level and.or decentralized departmental operational databases. This approach is typical of many client/server applications today, which allow business users to access operational databases through database gateway middleware. The third approach involves creation of an informational database by copying data from the operational databases, and then providing the end user with appropriate decision support (query and report) tools to access the data in the information database, again through database middleware. This approach reduces the performance impact of end-user decision support processing against the operational databases. The final approach is similar to the third, except that now the information database is formally structured, and the data is transformed to enhance its functionality. This approach, the enhanced informational database, is the data warehouse concept.

Four attributes distinguish the data in a data warehouse: subject-oriented, integrated, time-variant, and nonvolatile. The data is organized around major subjects, not processes. The data has consistent data element definitions and consistent data structures in order to integrate the multiple sources and types of operational source data. The data provides a historical perspective, because it is accurate as of specific moments in time; in effect, the data provides a series of "snapshots" taken over a long time horizon.

Finally, the data does not change over time; data is added to the warehouse, but the data in the warehouse is never changed (unless to correct an input error). (Inmon, 1994; Ashbrook, 1993; Wallace, 1993)

W.H. Inmon, author of the landmark work on data warehousing, *Building the Data Warehouse* (QEI Press, Wellesley, Massachusetts), lists the following structural components of a data warehouse: meta data, current detail data, older detail data, lightly summarized data, and highly summarized data. Figure V.10 graphically depicts this structure. The primary component is the current detail data, which is the most recent data, stored at the lowest level of granularity. Older detail data is infrequently accessed, so it is usually stored on some form of mass storage that does not provide instant access to the data. The lightly summarized and highly summarized data provide multiple levels of aggregation, resulting in compact and easily accessible data. Meta data provides the directory to help an analyst locate specific contents in the data warehouse; guides the mapping of operational data through its transformation to the data warehouse data structure; and defines the algorithms used for the summarization and aggregation. Figure V.11 provides an example of the different levels of data aggregation. Figure V.12 provides an example of the internal structure of

the current detail data component of a data warehouse structured for a manufacturing environment. (Inmon, 1994, p. 1-15)

Other data is frequently stored within the data warehouse even though it is not derived from operational data. Data obtained from external sources, such as commercially available demographic data and market analysis data, is a frequent addition to the types of data stored. Another type of data stored is data required to be permanently maintained at a specified level of detail for ethical or legal reasons, such as occupational health and safety records. Finally, public summary data is internal data that is calculated outside the boundaries of the data warehouse, but used throughout the organization. An example of public summary data is the quarterly reports prepared by public corporations for the Securities and Exchange Commission (SEC). (Inmon, 1994, p. 15; Ferrara and Naecker, 1993)

Data warehouse management software consists of four tools: the data warehousing software, which provides the user-specified transformations of the operational data; the data warehouse DBMS, which is usually any relational DBMS, (although specialized RDBMSs also exist); data access and reporting tools, which provide the end-users the means to obtain and manipulate the data; and the database connectivity software, or middleware, which allows the end-user front end

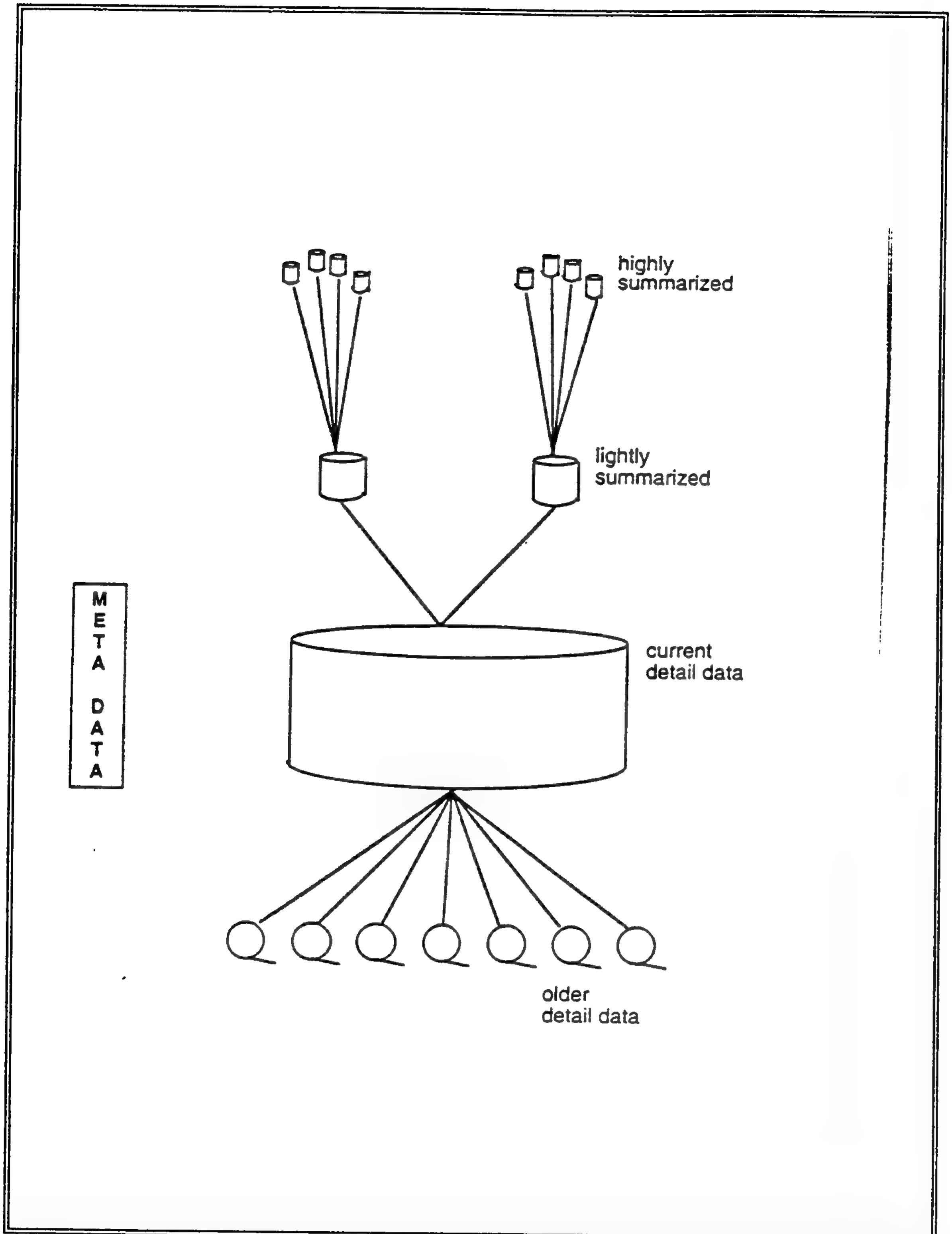

Figure V.10 The structure of data inside a data warehouse (Inmon, 1994, p. 7)

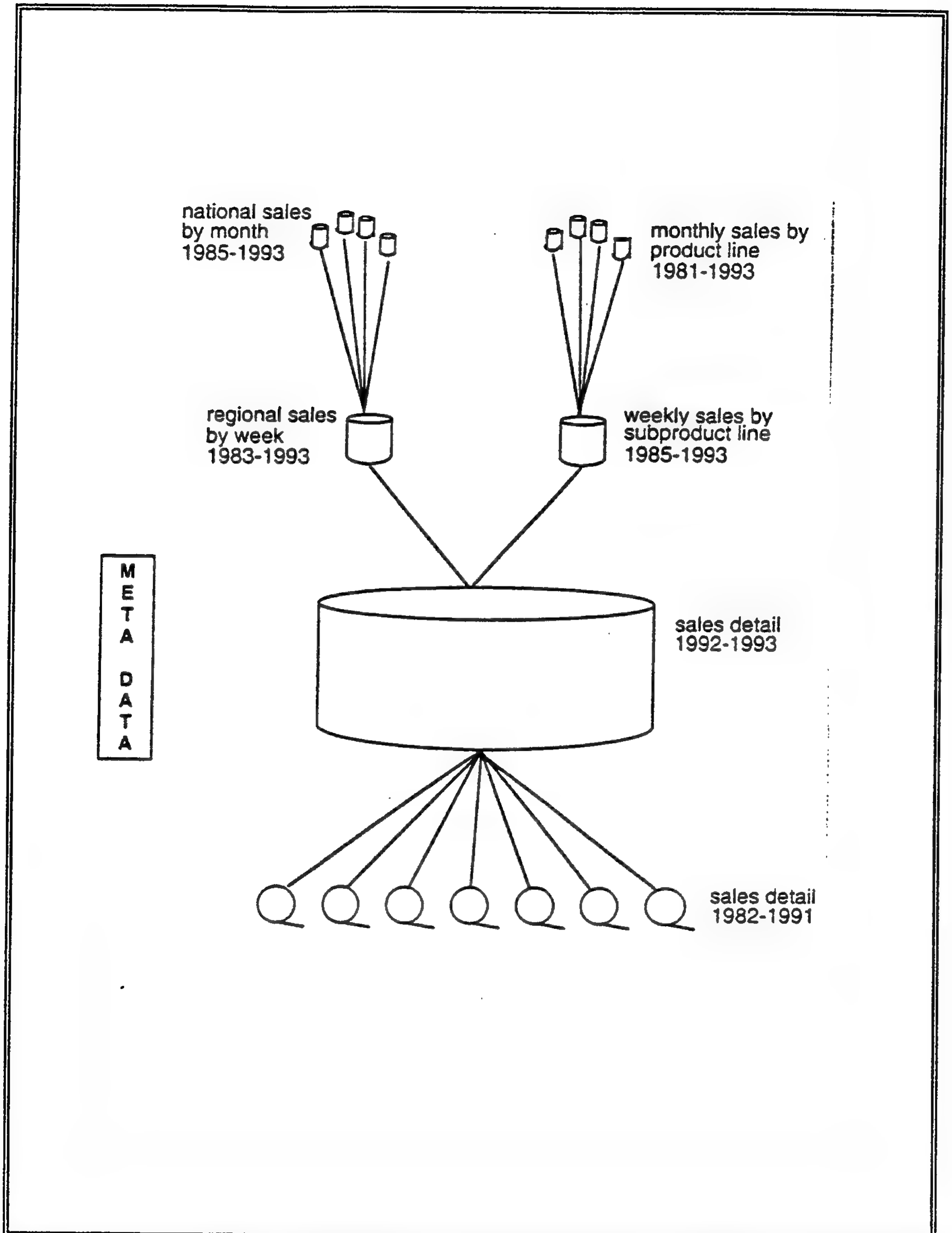

Figure V.11 Data warehouse data aggregation example (Inmon, 1994, p. 9)

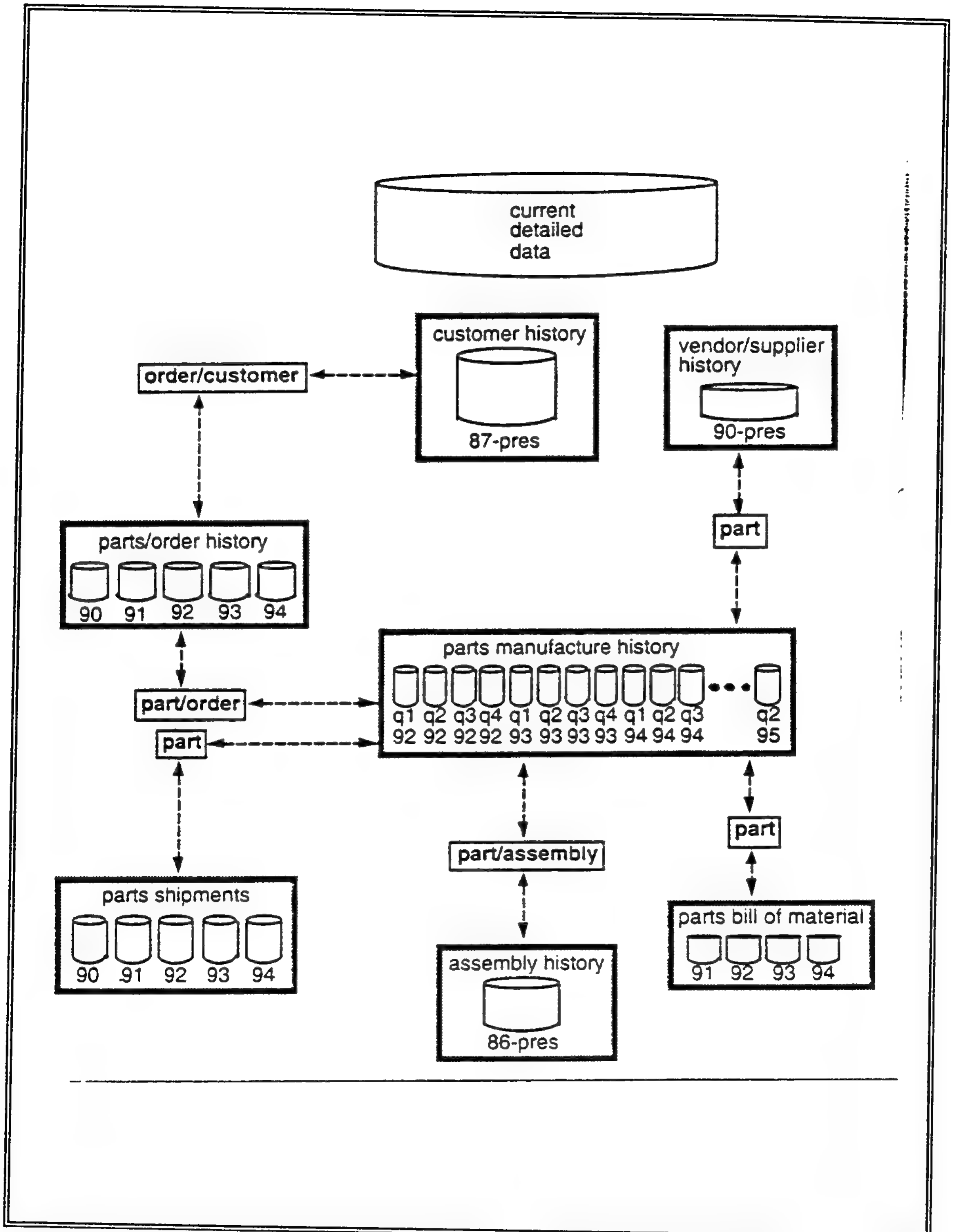

Figure V.12 Current detailed data internal structure (Inmon, 1994, p. 14)

applications to communicate with the databases. Numerous vendors provide products for each of these types of tools.

B. CHAPTER SUMMARY

This chapter provides a technical overview of the many different types of data management approaches available to support development of systems to implement an information architecture. One or more of these technologies apply to any attempt to define the Naval Postgraduate School's information architecture implementation. The next chapter discusses the steps involved in an analysis of the NPS requirements and these different alternatives.

VI. NPS REQUIREMENTS AND DATA MANAGEMENT ALTERNATIVES

Systems Analysis and Design literature contains numerous discussions of the different methods for conducting requirements analysis; most of these methods generally have several points in common. Federal and DoD acquisition regulations also address requirements analysis, and provide specific guidance on minimum requirements. This thesis research uses the information system (IS) requirements and alternatives analyses guidelines found in the *Federal Information Resources Management Regulations* (FIRMR)(41 CFR 201), supported by the discussions in a supplemental guide published by the General Services Administration (GSA), *A Guide for Requirements Analysis and Analysis of Alternatives* (GSA-IRMS, 1990). The FIRMR identifies numerous factors to be considered during any IS requirements analysis; these are briefly outlined in the first section of Appendix F. Similarly, the FIRMR includes several procedures for the conduct of the analysis of alternatives; these are briefly described in the second section of Appendix F.

The first section of this chapter contains the NPS information architecture requirements analysis conducted for this thesis, and the second section contains the data management architecture alternatives analysis.

A. ANALYSIS OF NPS INFORMATION ARCHITECTURE REQUIREMENTS

This analysis[8] of NPS information architecture requirements does not strictly conform to the guidance in the FIRMR and the GSA supplemental guide. An information architecture is not a system; therefore, requirements analysis procedures designed for systems are not entirely suitable for use in this case. However, the analysis of the requirements for the NPS information architecture attempts to incorporate as many points from the FIRMR and GSA guide as possible.

The requirements analysis process includes gathering information on the following: the NPS mission, NPS functional areas, and NPS organizational information needs; the current NPS information architecture and its component parts; and a projection of future NPS needs, drawing upon NPS Component Information Management Plans (CIMP) and the draft NPS Information Systems Vision proposed by the Computer Advisory Board (CAB).

The information collected consists of overall and top-level overview data, as described and analyzed in Chapter IV. This requirements analysis only covers the area of the information architecture, and no other related issues -- such as supporting system technology and network infrastructure requirements. Due to the top-level overview nature of this

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[8]The FIRMR policy regarding requirements analysis states that the scope of the analysis should be "commensurate with the size and complexity of the needs" (41 CFR 201-20.102).

approach, this requirements analysis is also only a broad overview of a future NPS information architecture's requirements, and [regrettably] not a very detailed or in depth analysis. A full requirements analysis requires a significantly more in-depth analysis of not only the current information architecture but also all the supporting infrastructure and technology issues to refine the needs.

1. Information Needs or Requirements

The factors that determine and define NPS's information needs with respect to an information system (or architecture) are many and varied. The following listing only provides a broad overview of each factor, not the detailed and comprehensive analysis that would be required to fully determine the detailed requirements. The factors include:

a. Information Sources

Information sources identify the information currently being received in the organization, from internal and external sources, and address the issue of missing information.

(1) Internal Information Sources. Internal information sources are the sources within the NPS organization that generate information used in information systems throughout the enterprise. These sources directly correlate to the organizational units responsible for the creation of data entities (instances of a data entity type)

identified in the Chapter IV analysis; therefore only a partial listing is included here in Table VI.1 as an example.

Table VI.1 INTERNAL INFORMATION SOURCES

Information Source	Data Entity (Information)
Academic Chairs, Dean of Instruction	Academic Course Instruction
Provost/Academic Dean	Academic Dept or Group
Academic Associates, Academic Chairs	Academic Plan
Academic Associates, Academic Chairs	Academic Program
Curricular Officers, Director of Programs	Curricular Plan
Curricular Officers, Director of Programs	Curricular Program
Superintendent	Agreement
Director of Resource Management, Comptroller	Appropriated Fund
Director of Admissions, Dean of Students	NPS Student

(2) External Information Sources. External information sources are the sources outside the NPS organization that provide information used in information systems throughout the enterprise. Table VI.2 provides examples of external sources.

Table VI.2 EXTERNAL INFORMATION SOURCES

Information Source	Data Entity (Information)
Major Claimant, Resource Sponsor	NPS Budget
Office of Personnel Management, SECNAV	Civilian NPS Faculty, Civilian NPS Staff
Curriculum Sponsor	Curricular Program, Curricular Plan
Chief of Naval Personnel (BUPERS)	Military NPS Student. Military NPS Staff

(3) Missing Information. Missing information is the internal or external information that is needed by a user but is not currently being determined or received. Every organizational unit, from the highest level to the lowest level in the organization, has missing information. Table VI.3 provides examples of missing information.

Table VI.3 MISSING INFORMATION

Organizational Unit	Missing Information
Provost	NPS output measurements
Provost, Dean of Faculty	Faculty background data
Comptroller	Dynamic budget data updates
Academic Associates	Student data

b. Information Outputs

Information not only flows into the organization, but also flows outward, in the form of information outputs.

(1) Information Outputs to Agencies. NPS organizational units provide information to many external agencies. Table VI.4 provides examples of information outputs to other agencies.

Table VI.4 INFORMATION OUTPUTS TO AGENCIES

Information Output	Agency
Curricular Programs	Curricular Sponsors
POM Budget Submission	Comptroller of the Navy
Accounting Data	Navy Regional Finance Center
Financial Audits	Navy Audit Service

(2) Information Outputs to the Public. NPS also provides information directly to the public, as opposed to agencies. Table VI.5 provides examples of these types of information outputs.

Table VI.5 INFORMATION OUTPUTS TO PUBLIC

Information Output	Public Organization
Press Interviews	Local area media representatives
News Releases	Local area media representatives, general public
Command Newspaper	General public
Query Responses	Local area media representatives, general public

c. *Information Relationships*

Information relationships, or data entity relationships, define how the data entity types within the NPS enterprise relate to one another. The Chapter IV analysis provides a discussion of the data entity type relationships, listed in Tab D of Appendix D, and is not repeated here.

d. *Quantity of Information Required*

The amount of information processed by the various information systems that make up the current information architecture at NPS varies widely. Table VI.6 provides specific examples, such as the number of records processed, number of copies of an application required, or the type and frequency of system use.

Table VI.6 QUANTITY OF INFORMATION

Information System	Quantity
Student Academic Records System (STARS)	> 1,800 student data records -- quarterly scheduling
Banyan Vines Administrative LAN	> 875 users, only 600 available workstations
Computer Center Backbone Network	295 workstations and 100 IBM terminals
Minor Property Accountability System	> 15,000 minor property item records

e. *Information User Location*

Information user location data provides necessary background information for development of the technical infrastructure. Table VI.7 provides example user location data.

Table VI.7 INFORMATION USER LOCATIONS

Location	Number of Users
Various -- IN-141, I-364E, RO-222, Sp-311, BU-100	190
Learning Resource Center -- GL-128	34
Learning Resource Center -- GL-318	20
Learning Resource Center -- IN-151, IN-371	22
Learning Resource Center -- GL-203	35
Learning Resource Center -- R-262	20

f. *Information Timeliness*

Timeliness generally relates to the response time of data processing systems. Some types of information are needed immediately while longer response times are acceptable in other situations. Table VI.8 provides specific examples of timeliness requirements.

Table VI.8 INFORMATION TIMELINESS

Information	Timing
Individual student class schedule	Quarterly, approx. one week before end of quarter
Individual student grade	Quarterly, approx. one week after end of quarter
Base Realignment and Closure (BRAC) data call	Immediately, within 2-3 days
Congressional inquiry	Immediately, within 24 hours

g. Information Format

Information format drives the compatibility and interoperability issues, and applies at multiple levels of abstraction, from data element standardization for interconnected databases to common office automation application file formats. Table VI.9 provides examples of information format issues.

Table VI.9 INFORMATION FORMAT

Category	Compatibility
LAN Windows Applications	Install Windows on Server or on each PC
Download STARS mainframe data to PC database	Database and data element structures
Field Support Activity (FSA) budget reports	Standard report format
LAN Interconnectivity	Standard communications protocols

h. Information Security

Each information system at NPS has both common and specific security requirements. The range of information used in NPS systems varies from easily accessible public domain information through highly classified and compartmented information processed on secure systems. Table VI.10 provides a sample listing of the common security requirements for all

information systems, derived from Appendix B of the NPS Automated Data Processing Security Program instruction, NAVPGSCOLINST 5239.1A (30 November 1992).

Table VI.10 INFORMATION SECURITY

Requirements Category	Requirement
Environmental Requirements	Surge suppressors on all devices
Fire Safety Controls	Automatic smoke or heat detection equipment
Facility Maintenance/Cleanliness	Prohibit eating, drinking, and smoking in the vicinity
Temperature and Humidity	Follow manufacturer's recommended ranges
Water Damage Control	Provide plastic sheets for susceptible equipment
Media Control and Marking	Permanent operating system backup copies
Communications Security	Standard Operating Procedures for LANs
Protected Distribution System (PDS)	Log off or lock unattended terminals
Terminal Identification	Use logon banners
Access Management	Develop and enforce challenge and escort procedures
Security Software	Configure PCs to load anti-virus software at boot-up
Security Documentation	Specify security requirements in LCM documentation
Training	Ensure all users receive appropriate training
Physical Security	Lock computer spaces at close of business

i. Information Privacy

The Privacy Act of 1974 (5 USC 552a) levies specific requirements for record storage of information about individuals. Privacy Act information about an individual includes data on an individual's education, financial transactions, medical history, personal history, criminal history, employment history, or other identifying characteristic, such as finger prints, voice prints, or photographs. Table VI.11 provides examples of some of the requirements identified in the Navy's directive on

safeguarding personal information in ADP systems -- SECNAVINST 5239.1 (w/CH. 1: May 17, 1979).

Table VI.11 INFORMATION PRIVACY

Requirements Category	Requirement
Physical Security	Designate and post computer areas as controlled area
Information Management	Label all output products and storage media
	Destroy material as soon as intended purpose served
Computer System / Network Security Controls	Control access through computer verified passwords

j. Information Accessibility

Information accessibility actually covers a wide range of issues, but is generally interpreted as the need to provide access to disabled Government employees or members of the public. This applies not only to the need for physical access to the equipment, but also the need to incorporate appropriate technologies into the information systems to support disabled users. Table VI.12 provides examples of accessibility issues, as discussed in the FIRMR (41 CFR 201-20.103-7).

Table VI.12 INFORMATION ACCESSIBILITY

Requirement
Equivalent access to electronic office equipment
Telecommunications access to hearing-impaired
Telecommunications access to speech-impaired

k. Current System Description

The Chapter IV analysis describes the current system, which in this case is the NPS enterprise information architecture. The following subsections provide additional information.

(1) Current System Users. Table VI.13 categorizes some of the current system users by system or application. The users listed are a representative sampling of the whole user population.

Table VI.13 CURRENT INFORMATION SYSTEM USERS

Information System	Users
Student Academic Records System (STARS)	Registrar, Admissions, Curricular Offices
Admissions Student Information Database System	Registrar, Admissions, Curricular Offices
Curricular Officer Student Information System	Curricular Offices, Code 03
Navy Civilian Personnel Data System (NCPDS)	Personnel Services – Code 223

(2) Current System Functions. The Chapter IV analysis identifies the business functions supported by the various information systems at NPS. Tabs M and N of Appendix D provide additional data, including the functional decomposition of the activity hierarchy diagram, and the activity definition list.

(3) Current System Workload. Workload analysis consists of numerous issues, including growth and expandability requirements, data handling or transaction

processing levels by type or volume, and peak traffic loads by location. This research project does not provide any workload analysis.

(4) Current System Costs. System costs include not only the acquisition costs of the hardware, software, and installation, but also all the life cycle costs, including operator salaries, training, maintenance, etc. Table VI.14 provides a sample listing of acquisition costs for new systems as proposed by various organizational units in their fiscal year (FY) 1994 IS budget submissions. The table includes examples of life cycle costs where available.

(5) Current System Inventory. NPS is currently conducting a inventory of all automated data processing (ADP) equipment in conjunction with the NPS Minor Property triennial inventory. No consolidated list of equipment exists; each organizational unit is responsible for maintaining an inventory of ADP equipment in their custody. No attempt was made to evaluate the system components or adequacy of program and system documentation.

1. Current System Performance Evaluation

The performance of the current information architecture is a function of the technical infrastructure. In the current enterprise configuration of multiple independent systems, performance can only be evaluated through evaluations of each component, such as mainframe applications,

Table VI.14 INFORMATION SYSTEM COSTS

System or Project Name	Estimated Costs	
Dean of Faculty Centralized Maintenance	Contractor provided hardware support: Contractor provided software support: In-house and one-time repairs: Total:	125,000 125,000 100,000 $ 350,000
System Management Program Support System	Hardware: Software: Supplies/Other: Total:	250,000 70,000 50,000 $ 370,000
Aeronautics and Astronautics Computational Facility		$ 349.000
Distance Learning Resource Center		$ 225,000
Computing & Network Services (Computer Center)	Procurement: Operating Costs: Total:	343,800 656,000 $ 999,800
Computer Science Department Laboratories		$ 900,000
Defense Resources Management Institute System	Hardware: Software: Supplies: Maintenance: Total:	120,500 20,000 20,000 5,000 $ 165,500
ECE Department Academic Computing Facility		$ 503,000
Library Automation System	Procurement: Operating Costs: Total:	124,500 191,000 $ 315,500
Math Department Distributed Computer Facilities		$ 70,000
ME Department Distributed Computer Facilities	Hardware: Software: Supplies: Maintenance: Total:	961,000 75,000 34,000 15,000 $ 1,085,000
Meteorology Department Computing		$ 245,000
Information System Support (MIS)	Hardware: Software: Supplies: Maintenance: Total:	117,000 22,000 5,000 112,000 $ 256,000
Joint Deployable Intelligence Support System (JDISS)		$ 132,000
NSA Teaching, Research and Admin Systems	Hardware: Software: Supplies/Other: Total:	193,400 49 ,000 17,000 $ 259,400
Oceanography Computer Systems		$ 271,000
Physics Department Computer Facilities		$ 400,000
Space Systems Computing Facilities		$ 146,000
NPS Systems Technology Laboratory		$ 762,000

or LAN applications. No attempt is made in this project to conduct performance evaluations for the systems and components in the current architecture.

2. System Life

Based on the requirements for five-year strategic planning found in multiple governing directives, the "system life" for the next information architecture is arbitrarily projected to be 60 months.

3. Description of Requirements

The analysis of the information needs and requirements, and the evaluation of the current information architecture (albeit at a high level) leads to the following discussion of the NPS data management requirements:

a. Basis for Requirements

The basis for the requirements is support for the NPS mission. Chapter IV provides a discussion of the NPS mission, the strategic vision, and other objectives and goals; that discussion is not repeated here.

(1) Deficiencies in Existing Capabilities. The primary deficiency in the existing capabilities of information systems throughout the NPS enterprise is the inability to support management with timely information. This deficiency exists due to the decentralized nature of information systems management, and the related data management. Most information needed by NPS managers is often already available in some

system within the NPS enterprise; however, the manager does not have direct, immediate access to that information.

This information access problem has three aspects: first, the manager needs *information*, not just *data;* second, the manager needs the information in a timely manner; and third, the data or information may exist in multiple sources. The issue of information versus data generally refers to the manager's need for a more abstract or aggregated view of the underlying data; i.e., the manager does not want to count all the elements in the data report just to get the total sum. The issue of timely information refers to the manager's desire to have direct and immediate access to the information; i.e., the manager does not have to place a priority request to the keeper of the data and hope for a timely response. The issue of multiple sources for data needed by a manager is not easily overcome, however, solutions to this data access problem exist: the data may be stored in a central location, multiple copies of the data may be distributed throughout the enterprise, or specialized data access tools may be used to retrieve the data from wherever it is distributively stored. Key to the resolution of all these issues is providing interconnectivity among all the enterprise information systems, interoperability among systems and applications, and standardization of the corporate data.

(2) New or Changed Program Requirements. The NPS mission is not likely to change; the focus remains on providing students with a quality education, and conducting leading-edge technology research to support the Navy. However, as additional educational requirements emerge, NPS develops new academic programs to meet these demands. As technology evolves, new research ideas develop and require further study. These evolving requirements cause changes to business functions, and lead to a revision of the information architecture.

One example of a new trend in industry which is also beginning to develop at NPS is automated support for group or team projects. This automated support ranges from a simple capability to communicate among all the group members through electronic mail to the use of group decision support systems and two-way video-teleconferencing systems. Data and information management in such an environment presents additional complexities, and drives the NPS enterprise's information architecture and underlying infrastructure towards more capable and complex system structures.

(3) Increased Economy and Efficiency. The downsizing of the military forces and the supporting defense industry infrastructure as a result of the changing global environment has led to declining budgets for all organizations. This decreased funding drives an

organization's desires to economize and improve efficiency wherever possible. Efforts in this area at NPS include actions underway as part of being designated a "Government Reinvention Laboratory", and actions supported by the implementation of Total Quality Leadership (TQL). Another key driver for the NPS enterprise is the need to show Congress and the Base Realignment and Closure (BRAC) Committee that the NPS is a unique institution, more efficient and effective in the accomplishment of its mission than any other comparable civilian or military educational institution.

Automating business processes frequently improves efficiency and economy, but only if the business process is efficient and economical in the first place. The information architecture analysis provides a means to examine business functions, and determine if more efficient and economical processes exist.

b. Functional Requirements

The functional requirements for the data management aspects of any information architecture are directly connected to the functional requirements of the underlying technical infrastructure, including the network connectivity. The functional requirements are briefly stated as the ability for any authorized user to access any NPS enterprise information from any location, i.e., the

requirement exists for a fully interconnected and interoperable network, using standardized data structures.

c. *Applicable Standards*

No specific standards for an information architecture exist, therefore none are specified here. However, many higher level directives provide guidance on data standardization, system language specification, and other areas that are applicable to the implementation of data management strategies. Chapter II provides an overview of these directives; no further discussion is provided here.

4. Compatibility-Limited Requirements

There are no enterprise-wide compatibility-limited requirements (as defined by the FIRMR). Currently available technology satisfies all the requirements for system interoperability and compatibility. However, use of equipment that is directly compatible with existing system equipment leads to performance improvements.

5. Justification for Make and Model

Likewise, there are no enterprise-wide "make and model" restrictive requirements (as defined by the FIRMR). Currently available and projected future technology satisfies all the requirements for system interoperability and compatibility. However, use of specific make and model equipment may be desirable from a training learning curve perspective.

6. Security Requirements

Security requirements are specified in the NPS Automated Data Processing (ADP) Security Program instruction, NAVPGSCOLINST 5239.1A (30 November 1992), and are not repeated here.

7. Accessibility Requirements for Individuals with Disabilities

This project does not address specific accessibility requirements.

8. Space and Environmental Requirements

Space and environmental requirements are a function of the technical infrastructure, and are not addressed in this project.

9. Workload and Related Requirements

This project does not address workload requirements.

10. Records Management Requirements

This project does not address records management requirements.

B. ANALYSIS OF NPS DATA MANAGEMENT ARCHITECTURE ALTERNATIVES

Chapter V identifies the alternative architectures resulting from the market surveys; this section addresses those alternatives in terms of meeting the identified NPS information architecture requirements. As with the requirements analysis, this analysis of alternatives does not

conform to the guidance in the FIRMR and GSA guide, but attempts to include all areas of discussion.

1. Consideration of Alternatives

GSA's mandatory-for-use and mandatory-for-consideration programs do not address information architectures, and therefore are not investigated. However, these programs apply to any implementation of an alternative information architecture, since the programs provide equipment for meeting the supporting technologies and infrastructure requirements.

2. Cost for Each Alternative

The choice of an alternative determines which cost analysis method to use -- simple cost/benefit analysis or net present value of life-cycle costs analysis -- since the cost of some alternatives may be less than the $50,000 expected cost threshold. The proper implementation of any alternative concept investigated here quickly drives the costs over the threshold, and thus forces a full life-cycle cost evaluation.

The vendor-specific implementation of each alternative determines the majority of the costs associated with each alternative. Additionally, analysis of non-cost functional and risk factors requires the use of a vendor-specific implementation of each alternative with its supporting technological infrastructure. Therefore, no precise cost estimates exist in this analysis for each alternative.

The majority of recent industry data addresses the costs associated with client/server implementations. Client/server architectures are the current technological answer to the information processing issues raised by corporate downsizing of rightsizing. One study by the Datapro Information Services Group (1994) provides a relative assignment of client/server technology-related costs, shown in Table VI.15.

Table VI.15 CLIENT/SERVER TECHNOLOGY-RELATED COSTS

Technology	Implementation Cost	Training Cost
Client/ Server Hardware	45 %	05 %
Databases	22 %	14 %
Development Tools	21 %	29 %
Application Software	30 %	30 %
Network Software	19 %	12 %
Operating System	13 %	11 %
Consulting Services	17 %	14 %

Ellen Hufnagel (1994, p. 28) provides two strategies for rapidly assessing probable client/server implementation costs. The first strategy is a very simple "ballpark" approach: the number of potential end-users is multiplied by one of the following system costs:

1. "Bare-bones" system -- $ 31,500
2. Middle-of-the-road system -- $ 42,500
3. Full bells and whistles system -- $ 51,500

Using these values, installation of a 600 user middle-of-the-road client/server system to replace the NPS Banyan Vines

administrative LAN would cost approximately $25.5M, or over two-and-a-half times the estimated total NPS IS annual funding level.

The second strategy is a more detailed fill-in-the-blanks approach, and consists of two parts: identifiable or quantifiable costs, and hidden or unquantifiable costs. Table VI.16 provides a cost breakdown of the second strategy.

Table VI.16 ASSESSING CLIENT/SERVER COSTS

Identifiable/Quantifiable Costs	Hidden/Unquantifiable Costs
Hardware	**System Administration**
Client -- estimate $ 8,000 to $ 15,000 per end user	Estimate $ 500 to $ 700 per client per month
Server -- estimate $ 25,000 to $ 110,000 per 20 users	**Training**
Networks	Application coders w/o experience -- $ 3,500 each
Routers -- varying costs, assume most expensive	Application coders w/ experience -- $ 1,500 each
LAN -- installation charges	Users -- $ 1,000 each
External -- carrier costs and costs of redundancy	**Maintenance and Software Upgrades**
Software	Estimate 10 % of hardware/software purchase price
Operating Systems -- 10 % annually for maintenance	
Middleware -- 10 products X $ 50,000 to $ 250,000 ea	**Consulting Fees**
In-House Application Development	Estimate $ 145 to $ 195 per hour
Estimate $ 35 to $ 65 per project hour	

The second strategy does not provide a complete listing of costs since many of these costs are related to vendor-specific implementations (routers, LAN installation, etc.); therefore, a comparison of the costs determined from the two strategies is not possible.

3. Conversion Analysis

Selection of any alternative results in conversion requirements; the extent of conversion required differs

significantly. A brief description of the types of conversion issues associated with each alternative follows. This conversion analysis does not address costs, risks, or size of conversion; that requires a more detailed analysis of the current information architecture and all the supporting infrastructure technologies.

Conversion to a distributed processing information architecture requires true data management, including determination of physical database locations, data access methods, two-phase commit and synchronization procedures for the distributed databases, replication timing decisions, and a host of other issues. True distributed computing is still in its infancy throughout industry, primarily due to the lack of adequate industry standards.

Conversion to a client/server processing information architecture, using the current mainframe as a server, requires addition of communications processors to interface with the network of clients, high speed printers for reports, adequate data storage and data backup capabilities, and gateways (middleware) to provide database interoperability and character coding language translation.

Conversion to a client/server processing information architecture, using dedicated servers, requires as a minimum the selection of appropriate servers, based in part on the server's operating system; selection of appropriate client

workstations; porting or redesigning applications to the new environment, and training of users and technicians.

Conversion to an information architecture that uses a data warehouse requires selection of a relational DBMS for the warehouse, selection of a data warehousing tool to provide the data extraction and aggregation services, and selection of a data access tool to retrieve the data from the data warehouse for analysis.

Conversion to an information architecture that simply uses data access tools as front ends first requires selection of a data access tool robust enough to interface between multiple front-end hardware platforms and multiple back-end databases. Additional requirements include enabling full interconnectivity between systems, i.e., establishing an adequate technical infrastructure; and conducting training for users and technicians.

4. Obsolescence Analysis

Due to the rapid pace of technological change within the computer industry, and the rapid rise and fall of many vendors, the process of predicting obsolescence is very difficult. The concepts identified as possible alternatives for an information architecture are technologically stable. However, vendor-specific implementations of each concept change frequently as new standards and vendor alliances are created. Selection of any of the listed alternatives provides

a data management architecture which will remain viable for the projected lifetime duration.

5. Capability and Performance Validation

As discussed in Appendix F, the FIRMR allows each organization to select the methods to be used for capability and performance validations.

a. Capability Validation

The description of each data management alternative provided in Chapter V addresses only the concept, not the actual implementation by any particular vendor or set of vendors. Therefore, the method chosen for capability validation is examination of the technical literature, supplemented by vendor certification of conformance with functional requirements. Vendors willingly provide extensive information related to their products, ranging from glossy sales brochures to very technical literature, including white papers and independent analyses of the vendor's products. In some cases, vendors provide free seminars and hands-on demonstrations of their products. Review of the available technical literature, and attendance at numerous trade exhibitions and vendor seminars, provides this researcher sufficient technical background to perform a conceptual capability validation.

Using these methods, only the data warehouse alternative fails to meet all the functional requirements.

Current data warehouses (and data warehouse tools) store aggregate operational and other data for use in organizational Decision Support Systems (DSS) or Executive Information Systems (EIS), but do not provide a good capability to readily access discrete data. Therefore a data warehouse is not recommended as the sole method of data management; however, use of a data warehouse does provide significantly improved access to common corporate data. Discussions with vendor representatives and system integration specialists reveals that industry is investigating better methods to access and use the information stored in a data warehouse, but no specific methods have been identified to date (Haderle, 1994).

b. Performance Validation

Performance validation applies only to specific implementations of each generic alternative, not to the conceptual alternative itself. Since this analysis did not examine specific implementations, no performance validations were conducted.

6. Overall Data Management Architecture Conclusions

Four of the five alternatives discussed provide the required ability for an authorized user to access any NPS enterprise information from any location; the exception is the data warehouse as discussed in the previous section. Each alternative has advantages and disadvantages.

The overriding disadvantage of the fully distributed processing information architecture is the lack of technological maturity within the technical infrastructure and lack of industry standards. These disadvantages will remain for the duration of the projected lifetime (five years), but will disappear as the standards are accepted throughout industry.

The primary disadvantage to a client/server processing information architecture is the high initial cost of conversion of the technical infrastructure; these costs include the costs of establishing a network that provides the required interconnectivity, the costs of porting all the applications to the new platforms and operating systems, and the costs of standardizing (converting) the data to a common format. The principal advantage is the degree of industry support for the client/server information processing concept, with numerous vendors providing a wide range of client/server-related products, scalable up to multiple massively parallel processing systems.

A data warehouse conceptually provides access to vast amounts of corporate data; however, not all the NPS enterprise data belongs in a data warehouse. Therefore, this solution provides at best only a partial solution for data management at NPS.

The use of data access tools or other middleware is a stopgap solution, which only postpones the inevitable

conversion to a more distributed processing environment. As such, the use of middleware has a strong role as a transition mechanism to a client/server or other form of distributed information processing architecture. Selection of an appropriate middleware tool provides a means to provide continued or parallel access to corporate data during the migration to a more distributed information processing architecture.

C. CHAPTER SUMMARY

This chapter provides discussion in two areas: an analysis of the NPS information architecture requirements, using a loose application of the FIRMR's analytical methods (described in Appendix F); and an analysis of the data management alternatives, again using a loose application of the FIRMR's analytical methods (also described in Appendix F).

The next chapter provides the actual conclusions and recommendations as a result of combining these two analyses with the NPS enterprise and information architecture analyses of Chapter IV.

VII. THESIS CONCLUSION AND RECOMMENDATIONS

This chapter provides the author's conclusions and recommendations in four areas: a data management architecture for the NPS enterprise in light of resource constraints; the study underway by the Provost's Committee on NPS Mission Organization; use of the information engineering methodology and the IEF™ CASE tool; and follow-on study and analysis efforts.

A. DATA MANAGEMENT ARCHITECTURE FOR NPS

This section provides the recommendations for a data management architecture resulting from the analyses of the NPS enterprise information architecture in Chapter IV, the NPS information needs in Chapter VI, and the available data management architecture alternatives in Chapter V. The author cautions the reader to keep in mind the following: the high-level overview nature of the analyses conducted does not provide the normal full justification required for the actual selection of any data management architecture alternative; the author's conclusions and recommendations simply provide a hint of a strategic direction or path for NPS to pursue based on the author's research and analysis results.

1. Data Management Architecture Conclusions

The available financial and personnel resources, discussed in Chapter IV, do not support immediate implementation of the data management architecture recommendations, unless funding is reprogrammed and additional personnel become available. One solution to the funding problem is distribution of the transition planning phase tasks as collateral assignments to personnel involved with the various existing departmental information system projects. Another solution is incorporation of the desired data management architecture into an existing departmental information system project as a pilot program for testing and evaluation, before expanding to the entire enterprise.

The discussion of the recommendations does not address the many related issues associated with the implementation of the data management architecture alternative, such as conversion costs, hardware and software requirements, and personnel training requirements. These issues depend on vendor-specific implementations, and are not addressed here.

2. Data Management Architecture Recommendations

Implement an enterprise-wide client/server information processing architecture. Client/server technology does not provide all the functionality of a fully-distributed information processing system; however, unlike distributed processing technology, the client/server technology is mature

and relatively stable. Multiple vendors provide scalable client/server implementation solutions that meet or exceed the NPS enterprise needs and requirements. Therefore, a client/server data management and information processing architecture is the recommended choice.

The implementation of a client/server data management and information processing architecture will not occur all at once; several phases exist in the transition path. Implementation of an enterprise-wide client/server architecture requires a significant underlying technical infrastructure. The existence of an adequate network infrastructure is an implicit and explicit prerequisite to the use of a client/server architecture. Interconnectivity and interoperability throughout the enterprise is necessary to provide any (authorized) user with the ability to obtain data from any data location. Therefore, the technical network infrastructure must first be put into place.

System performance requirements dictate the eventual migration to a single database management system. The actual choice of a specific DBMS is a vendor-specific implementation issue, which is not addressed here. The migration to a single specific DBMS includes a transition period of undetermined duration. During this transition phase, multiple DBMS and multiple databases exist until the data can be converted to the new DBMS' database format. Middleware data access tools provide the means to maintain access to legacy data in the

multiple different databases until the data conversion is complete. Therefore, selection and use of an appropriate middleware data access tool is critical to the successful implementation of the client/server architecture. It is important to note that the use of multiple types of DBMSs linked through an appropriate middleware data access tool only provides a short-term solution, since the overhead induced by the middleware prevents the system from meeting performance requirements.

The selection of the specific DBMS to be used often drives the selection of server hardware platforms. Occasionally, a desire to use an existing hardware platform for a server, such as a mainframe computer, will drive the decision of which DBMS to use. DBMS vendors continue to expand the portability of their systems to include interoperability with multiple hardware vendors and multiple operating systems. Eventually the selection of a particular server hardware platform will depend solely on performance characteristics. For NPS, use of the mainframe computer as a high storage capacity database server provides a means to more fully utilize the mainframe's capabilities while transitioning to a distributed network of dedicated database servers.

Conversion of data to a single DBMS database structure also provides an opportunity to fully implement data element standardization throughout the NPS enterprise. The transition phase supports parallel data element standardization efforts

by departmental data managers to minimize the length of the transition. A common enterprise-wide data dictionary results from the coordinated standardization efforts of all data users and managers.

B. NPS MISSION ORGANIZATION STUDY RECOMMENDATIONS

As previously mentioned in Chapter IV, the timing of this project report coincides with an effort by the Provost/Academic Dean to determine whether or not structural changes are required for the NPS organization. A summary of the author's recommendations regarding this study follow:

1. Divide the overlapping functions of the Dean of Faculty (Code 07) and the Dean of Instruction (Code 06) between the two offices. The Dean of Faculty functions relate to personnel issues; the Dean of Instruction functions relate to academic issues.

2. Shift the Dean of Students/Director of Programs military coordination of curricular programs and curricular review functions to the Dean of Instruction. Shift the Dean of Students/Director of Programs military faculty selection function to the Dean of Faculty.

3. Maintain the Dean of Research (Code 08) position.

4. The overlapping functions of Deans in the matrix organization hinder effectiveness and efficiency, and should be eliminated.

5. A proposed solution for the Code 05 dilemma is a central organization combining the functions of Computer Services and Information Services, headed by a professional, experienced Corporate Information Officer reporting directly to the Superintendent. The central organization responsibilities include all common infrastructure issues; every department/code provides operation and maintenance for their specific systems, coordinated through the central organization.

6. The functions performed by the Assistant to the Provost duplicate the functions performed (or assigned) to numerous other organizational codes at NPS. Restoration of all these functions to their assigned codes has the potential to significantly reduce the amount of duplicative and unproductive effort; key to this shift of responsibilities is the improvement of management information access for the Provost/Academic Dean.

7. Responsibility assignments for specific functions are: The Dean of Instruction for new instructional programs; the Dean of Research for new research centers; the Dean of Instruction for new instructional laboratories; the Dean of Computer and Information Services for distance learning facilities; the Director of Programs for international programs.

Chapter IV provides the full discussion of the author's conclusions and recommendations regarding this study.

C. EVALUATION OF INFORMATION ENGINEERING AND IEF ™

This section provides the author's evaluation of the information engineering methodology as an analysis approach, and the effectiveness of the automated implementation of the information engineering methodology in the TI IEF™ CASE tool.

1. Information Engineering Methodology Evaluation

The information engineering methodology provides an effective tool to analyze an organization, develop an information architecture, and even design and implement information systems to support an organization's business areas. The data-oriented premise of the methodology approach provides information engineering with its greatest strength: the stability of the generated data models. Another strength is the methodology's flexibility during the early phases --

numerous alternative methods exist for obtaining the organization's policies, objectives, and strategies.

Zeiders (1990, p. 32) cites the requirement for significant upfront user involvement as a potential weakness to the use of information engineering. User involvement is really a function of the specific application development scenario, not necessarily of the methodology itself.

The principal advantage that the information engineering methodology has over any other methodology is the support over the entire systems lifecycle, from strategic planning to full systems implementation. Therefore, the author's analysis serves as a basis for future system developments, and can be integrated into the lifecycle.

2. IEF™ CASE Tool Evaluation

The IEF™ has significant capabilities as an integrated CASE tool. This project did not use the full capabilities of the CASE tool, and thus encountered significant limitations. The heart of the IEF™ CASE tool is the Central Encyclopedia, which resides on a mainframe computer, and is accessed through the individual user workstations. The IEF™ tool set used for this project did not include the mainframe component (not available at this site), and thus did not use the Central Encyclopedia capabilities; a single workstation contains all the toolsets available for the project.

The lack of a Central Encyclopedia prevents integrated version control. An analyst can not integrate specific models, such as the data model or the activity model, derived from multiple versions of the overall organization model. Therefore, when an analyst follows one approach and reaches a dead end (as this author did on several occasions), there is no graceful recovery method. The analyst uses a copy (if made) of an earlier version as a baseline, and all the correct unrelated data is re-entered into the model, or else the model is recreated from the beginning. A Central Encyclopedia maintains multiple versions of the same model, and allows a user to select portions from each version to create another version, negating the need to start over again. The lack of a Central Encyclopedia is a significant limitation.

Chapter IV discusses numerous analysis artificialities due to limitations of the CASE tool. A summary of these and other limitations follows:

1. The Organizational Hierarchy Diagram (OHD) tool does not provide the capability to diagram organizational support functions (i.e., organizational units that provide support to multiple other units in the hierarchy) or matrix organizational structures, such as NPS' organization. Only tree-like hierarchies are supported.

2. Matrices used to describe the interrelationships between business functions and other planning objects do not include all the defined functions in the Activity Hierarchy Diagram (AHD). Only the lowest level function in any individual decomposition within the overall hierarchy is included. This limitation prevents evaluation of numerous functions that may decompose through multiple levels before reaching the lowest level.

3. Similar to the problem with functions in matrices, data entity subtypes are not represented in matrices. This prevents the evaluation of any data entity subtype, significantly limiting the level of detail in an analysis.

4. Definitions of the relationships between data entities are not movable, i.e., if a change is made to a data model that results in partitioning a data entity into subtypes, the relationships can not be moved to correspond with the particular subtype; relationships must be deleted and recreated at the appropriate locations.

5. Matrices which define the interrelationships between functions/processes and data entities, or organizational units and data entities limit the description of the relationship to a single code from the four available codes: Create, Read, Update, Delete. This prevents a full detailed description of the actual relationship.

6. Data entry in the various specific toolsets is a tedious and time-consuming process, and methods to allow more rapid data entry would significantly improve the CASE tool's usability.

7. Hard copy (printed) report options within each toolset provide no capabilities. Although three font styles and multiple font sizes exist for screen displays, the printed reports use only one font, which is system generated based on the desired report, and not controllable by the user. Graphical models can not be printed to a file; therefore large graphical models can not reduce to a viewable size with any level of detail. Text-based models can only be printed to a file using ASCII text or ASCII graphics. Conversion from the resulting text files to a word processing software format requires significant manual data clean-up and conversion.

8. The CASE tool saves the organizational model and all model subsets in four data files, which continue to grow and expand in size as additional detail and interrelationships are defined within each toolset. Alternate data backup methods must be used to provide a backup copy of the model in case of platform failure. Multiple versions of the same model quickly overwhelm the memory capacity of the desktop workstation.

D. FOLLOW-ON STUDIES AND ANALYSES RECOMMENDATIONS

This section addresses the recommendations for further studies and analyses. Chapter IV identifies numerous limitations to this project's analysis which should be resolved if this project will serve as the basis for follow-on study using the information engineering methodology. A summary of the projected requirements includes:

1. Redefine the business activities/functions in terms of the DoD Enterprise Activity Model functional areas and functional activities.
2. Once specific organizational goals are identified by the NPS management (through the Executive Steering Committee), complete the analysis of the goals and problems.
3. Once specific organizational critical success factors (CSFs) are identified by the NPS management (through the Executive Steering Committee), complete the analysis of the CSFs.
4. Building on the previous two analysis activities, conduct a strategic information systems study to formally identify the mission-critical information systems.
5. Obtain user feedback on the organizational activity and data models from all NPS organizaitonal units.
6. Obtain a complete listing of all information systems throughout the NPS enterprise, including the interfaces with all external systems, through terminals or modems.
7. Prioritize the business area system developments.
8. Complete the full Business Area Analysis (BAA) for each business area, refining the data model and activity model to its ultimate detail.
9. Based on the results of the full BAA, determine recommendations for organizational structure change.

As noted, the analyses may lead to reengineering processes and restructuring the NPS organization to support improved

efficiency and effectiveness. The results of these analyses provide enhancements to the analysis of the NPS requirements; further analysis in this area includes fully detailing the various factors addressed during the initial analysis.

In addition to the follow-on analyses of the NPS enterprise and its needs or requirements, another recommended study is the conduct of a more-detailed market survey to identify specific vendor solutions within each data management architecture alternative. Once vendor-specific implementation data is available, the alternatives require another (or further) analysis to identify the specific implementation solution.

E. FINAL CONCLUSIONS

This thesis research project attempts to answer two questions:

1. What is the information architecture of the NPS enterprise?
2. What is the most appropriate data management architecture for the NPS enterprise data, considering local constraints on both financial and personnel resources?

A high-level overview of the NPS enterprise information architecture now exists, as described in Chapters IV, VI, and the supporting Appendices. The answer to the question of an approriate data management architecture is the concept of a client/server information processing architecture, as described in Chapters V, VI, and this chapter.

APPENDIX A: AVAILABLE FEDSIM DOCUMENTS

The Federal Systems Integration and Management Center (FEDSIM) and the Office of Technical Assistance (OTA) in the Information Resources Management Service (IRMS) branch of the U.S. General Services Administration (GSA) routinely publishes documents which shares the information gained by FEDSIM in its work with other Federal agencies. These publications are also offered free of charge to Government organizations. A listing (titles and description) of some of the documents available from the IRMS, obtained from the FEDSIM 1st Qtr FY 1994 Listing, is included here:

A. FEDSIM Information Technology Publications

Single copies of the following documents are available free to Government organizations:

The Site License Approach to Acquiring Commercial Off-the-Shelf Software. A reference to assist agencies in the acquisition of commercial off-the-shelf software using site licensing. Provides an overview of factors to consider when deciding whether to use a site license and key elements in the preparation of a site license solicitation.

How to Buy Local Area Networks. Provides guidance to agencies considering the acquisition of a local area network

(LAN). The document addresses cost benefits; functional, physical, and operational requirements; design and integration; procurement; training; and maintenance issues.

Performing a Requirements Analysis for Acquisition of Federal Information Processing Equipment. Presents a methodology for conducting a requirements analysis for FIP equipment. Can be used as a reference for conducting a requirements analysis and preparing a requirements document (RA), and provides a broad view of the requirements process. Details the planning and technical aspects of the process and provides Federal managers with requisite procedures.

A Methodology for Conducting Federal Systems Integration Projects. Describes a structured methodology that Government agencies can use to conduct highly complex systems integration projects. The document defines systems integration within the context of the traditional systems life cycle, outlines the role of the systems integrator, and details nine specific step constituting the systems integration process. The document also discusses tools and techniques that can be employed to support systems integration projects and reviews the impact of, and expectations for, systems integration in the 1990s.

A Guide to Alternative Requirements Analysis Methodologies. A reference to assist agencies with choosing a information- and cost-effective methodology/technique for performing requirements analyses. Provides an overview of

three requirements-analysis methodologies -- Reverse Engineering, the Delphi Method, and the Interactive Design methodology.

Information Technology Facility Management Review and Evaluation. An Information Technology Facility (ITF) Management Review and Evaluation can lead to improved ITF management. Here FEDSIM shares experience gained by working with agencies on projects related to ITF Management Review and Evaluation.

Using Integrated Services Digital Network Technology. This document is a guide for Federal government planners and designers who are considering the use of Integrated Services Digital Network (ISDN) technology for the first time or who are involved in the actual selection and implementation of ISDN-based data communications networks.

Improving Information Technology Facility Management. Developed to promote efficient, effective, and economical Information technology Facility (ITF) management, this document provides an overview within the context of Federal IRM. It discusses four key management controls -- ITF management reviews and evaluations, capacity management programs, charging systems, and security programs. It describes FEDSIM's approaches to developing and implementing these important management controls.

FEDSIMposium, Volumes 1 and 2. A collection of articles on a wide range of information technology issues written by

FEDSIM personnel and published by *FEDERAL COMPUTER WEEK* in a column called FEDSIMposium.

Proceedings of the Symposium on Benchmarking and Alternatives August 1989. A FEDSIM Symposium, "Benchmarking and Alternatives," was held on August 2, 1989, to provide current information to agency and vendor personnel on benchmarking and alternative methods of performance validation in acquisitions of computer systems. This document includes an abstract of each presentation and reproductions of the slides used during the presentations.

Designing Data Communications Networks. This document was prepared to help Federal managers and analysts design, evaluate, and select wide-area data communications networks for certain classes of military and agency-unique requirements. It shares information gathered by FEDSIM in the conduct of projects related to the design of wide-area data communications networks within the Government and provides tools for requirements determination, performance prediction, and topology optimization.

Information Technology Installation Security. This publication, addressed to Federal managers having responsibility for information technology installation assets, provides an overview of computer security-related laws, policies, regulations, standards, and guidelines and the organizations responsible for their enactment. It defines the components of a security program and provides procedures for

developing, implementing, and maintaining a practical and effective security program.

Model for the Acquisition of Software Support Services. Provides agencies with a strategy and methodology for acquiring software support services. Includes a model RFP and Proposal Evaluation Plan.

Capacity Management. Provides helpful information to agencies on managing the capacity of their systems. It is based on FEDSIM's experience with Federal implementations. The practical advice included here will assist managers in understanding and implementing a comprehensive capacity management program.

Survey of Life Cycle Management Methodologies. A survey of 23 documents being used throughout the Federal Government and private industry pertaining to life cycle management of information resources. Identifies the methodologies' characteristics and documents conclusions FEDSIM derived from the survey.

A Phased Approach to Life Cycle Management. Presents an overview of a life cycle management methodology developed by FEDSIM for information resources which includes phases and tasks neglected or underemphasized in other methodologies. Special emphasis is on system acquisition and planning.

Planning for and Acquiring Data Communications Networks. Provides specific guidance to agencies seeking to procure major data communications systems. Provides a high-level

overview of the five phases of the acquisition process, focusing on the management, planning and production of required documents.

Charging Systems for Information Technology Services. This document provides guidance to Federal managers on implementing charging systems in their information technology facilities. It is a practical guide, based on the experience of FEDSIM with Federal implementations, and will assist managers in: understanding the requirements of charging systems, developing an implementation strategy, sizing the level of effort required, and avoiding pitfalls experienced by others.

B. Other Information Technology Publications

The following documents/products are examples of other items that may be purchased from the National Technical Information Service (NTIS), U.S. Department of Commerce:

Programmers Workbench Handbook. Describes a practical approach to planning, acquiring, organizing, coordinating, and implementing automated tools.

Software Conversion Lessons Learned Volume 1. By using a series of case studies, this book provides the reader with the knowledge and experience gained from Government agencies and private companies who converted major ADP systems.

Conversion Cost Model (Version 4). IBM PC compatible software for estimating the resources necessary to accomplish a software conversion.

Conversion Plan Outline. This book provides a sample comprehensive outline for software conversion planning.

Guidelines for Planning and Implementing a Software Improvement Program (SIP). Serves as a starting point for establishing, planning, and implementing a software improvement program (SIP). Emphasizes the top-down incremental approach to software improvement and explains what you need to do to set up a SIP in your organization.

The Software Improvement Process -- Its Phases and Tasks (Parts 1 and 2). This report goes into great detail discussing the phases and tasks needed for planning and implementing a software improvement program (SIP).

A Software Tools Project; A Means of Capturing Technology and Improving Engineering. An introduction to the concepts of automated software tools and what they can contribute toward the software engineering process.

Software Improvement - A Needed Process in the Federal Government. An easy-to-read introduction to the concepts of Software Improvement and how these concepts can be used to effectively modernize Government software.

APPENDIX B: FEDERAL INFORMATION PROCESSING STANDARDS

A. Federal Information Processing Standards (FIPS)

FIPS are individual standards related to automated data processing, and are categorized in one of five areas: hardware, software, application, data, and operations. Each category also has sub-categories, and some FIPS fall within more than one category, such as FIPS dealing with network protocols. The first FIPS were issued in the late 1960s by the U.S. Department of Commerce's National Bureau of Standards, now known as the National Institute of Standards and Technology (NIST). The majority of the technical FIPS adopt American National Standards (ANS) for automated data processing developed by the American National Standards Institute's (ANSI) X3 Committee (Computers and Information Processing). Some adopt International Standards approved by the International Standards Organization (ISO), or joint ISO/ANSI standards. Many FIPS are simply non-mandatory guidelines written to serve as technical references for IS personnel in some area of information processing. Some of these standards have been adopted and implemented commercially as well. The Federal Standards are periodically reviewed, and the FIPS are revised or superseded if required whenever the underlying ISO or ANSI standards are updated.

The FIPS are too numerous to attempt to list and describe in their entirety. Even listing just the FIPS that can be considered applicable to information processing or information management at NPS would be excessive; therefore, only a small representative sampling of the applicable FIPS in each category is provided here.

a. *Hardware Standards*

CODE FOR INFORMATION INTERCHANGE (FIPS PUB 1; November 1, 1968) establishes a standard 128 character code set for information interchange that corresponds to the American National Standards Institute's (ANSI) American National Standard (ANS) X3.4-1968 [also known as the American Standard Code for Information Interchange (ASCII)].

CHARACTER STRUCTURE AND CHARACTER PARITY SENSE FOR SERIAL-BY-BIT DATA COMMUNICATION IN THE CODE FOR INFORMATION INTERCHANGE (FIPS PUB 17; October 1, 1971) specifies characters as seven ASCII bits and one character parity bit. This standard adopts ANSI ANS X3.16-1966, and specifies odd parity for synchronous transmissions and even parity for asynchronous transmissions.

LOCAL AREA NETWORKS: BASEBAND CARRIER SENSE MULTIPLE ACCESS WITH COLLISION DETECTION ACCESS METHOD AND PHYSICAL LAYER SPECIFICATIONS AND LINK LAYER PROTOCOL (FIPS PUB 107; October 31 1984) is a combined hardware and software standard. This computer network protocol standard adopts the

Institute of Electrical and Electronics Engineers (IEEE) standards 802.2 and 802.3, known commercially by the term Ethernet.

b. Software Standards

VOCABULARY FOR INFORMATION PROCESSING (FIPS PUB 11; November 15, 1970) adopts ANSI National Standard Vocabulary for Information Processing X3.12-1970 and provides an alphabetical listing of approximately 1,200 entries, each consisting of a term and its definition. This FIPS was superseded by the *DICTIONARY FOR INFORMATION PROCESSING* (FIPS PUB 11-1; September 30, 1977), which adopts ANSI's replacement standard X3/TR-1, American National Dictionary for Information Processing. FIPS 11-1 was superseded in May 1983 by an updated version. FIPS PUB 11-2 has since been superseded as well. The current FIPS is now *GUIDELINE: AMERICAN NATIONAL DICTIONARY FOR INFORMATION SYSTEMS* (FIPS PUB 11-3; February 1, 1991) which adopts ANSI Standard X3.172-1990 as a guideline for use by Federal agencies.

COMMON BUSINESS ORIENTED LANGUAGE (COBOL) (FIPS PUB 20; March 25,1972) adopts ANSI's COBOL (ANS X3.23-1968) as the Federal Standard COBOL.

GUIDELINE FOR PLANNING AND USING A DATA DICTIONARY SYSTEM (FIPS PUB 76; August 20, 1980) is a basic reference document which describes the capabilities of an automated data

dictionary system and provides guidance for selection and use of such a system.

GUIDELINE FOR PLANNING AND MANAGEMENT OF DATABASE APPLICATIONS (FIPS PUB 77; September 1, 1980) provides an early version of a basic reference which explains alternative software capabilities (then available) and provides recommended development practices for building database applications. Although the FIPS was issued based on 1970s technology, the general principles for database management system development still apply.

GUIDELINE ON INTEGRITY ASSURANCE AND CONTROL IN DATABASE ADMINISTRATION (FIPS PUB 88; August 14, 1981) serves as a basic reference which provides explicit guidance to achieve database integrity and security control. The FIPS also provides a step-by-step procedure for verifying a database's accuracy and completeness.

GUIDELINE FOR CHOOSING A DATA MANAGEMENT APPROACH (FIPS PUB 110; December 11, 1984) is a basic reference which helps identify the appropriate data management approach from among three basic options: traditional application system (file environment), database management system (DBMS), or a data management system (compromise between DBMS and file environment).

ADA (FIPS PUB 119; November 8, 1985) adopts ANSI's American National Standard Reference Manual for the Ada™

Programming Language, ANSI/MIL-STD-1815A-1983, as the syntax and semantic rules standard format for programs written in Ada™.

SPECIFICATION FOR A DATA DESCRIPTIVE FILE FOR INFORMATION INTERCHANGE (DDF) (FIPS PUB 123; September 19, 1986) adopts the joint ANSI and ISO Standard 8211-1985, which specifies media-independent and system-independent file and record formats for the transmission of information between computer systems.

GUIDELINE ON FUNCTIONAL SPECIFICATIONS FOR DATABASE MANAGEMENT SYSTEMS (FIPS PUB 124; September 30, 1986) is another basic reference document which helps IS managers prepare a contract paperwork for development of database management systems based on functional specifications. The guideline is divided into four areas: hardware and software constraints, global data factors, data model specifications, and other specifications.

DATABASE LANGUAGE SQL (FIPS PUB 127-1; February 2, 1990)(supersedes FIPS PUB 127 of March 10, 1987) adopts most of the ANSI SQL specifications in ANSI X3.135-1989 and ANSI X3.168-1989,and provides a database language for use in database applications founded on the relational data model.

COMPUTER GRAPHICS METAFILE (CGM) (FIPS PUB 128; March 16, 1987) adopts ANSI X3.122-1986 as a graphics data interface standard which specifies a device independent file format for use with graphical information.

STANDARD GENERALIZED MARKUP LANGUAGE (SGML) (FIPS PUB 152; September 26, 1988) adopts the ISO 8879-1986 Standard for specifying a language for describing documents that are processed by any text processing system.

GOVERNMENT OPEN SYSTEMS INTERCONNECTION PROFILE (GOSIP) (FIPS PUB 146; August 24, 1988) (revised and superseded by FIPS PUB 146-1; April 3, 1991) specifies a set of ISO's Open System Interconnection (OSI) protocols for computer networking that are intended for acquisition and use by Federal agencies. GOSIP is considered a combined hardware and software standard since it describes both types of products and services. The GOSIP FIPS is considered a mandatory standard, since it specifies that "GOSIP shall be used by Federal Government agencies when acquiring computer networking products and services and communications systems or services that provide equivalent functionality to the protocols defined in the GOSIP" (FIPS PUB 146-1, 1991, p.1). However, Federal agencies are still permitted to acquire network products other than those specified in GOSIP.

ELECTRONIC DATA INTERCHANGE (EDI) (FIPS PUB 161; March 29, 1991) adopts the nationally and internationally recognized family of standards known as X12 and EDIFACT. These standards were developed primarily to exchange business information, and support the transmission of all data associated with a particular type of functional document together as one electronic message.

c. *Data Standards*

CALENDAR DATE (FIPS PUB 4; November 1, 1968) was one of the first standards for formatting data.

STANDARDIZATION OF DATA ELEMENTS AND REPRESENTATIONS (FIPS PUB 28; December 5, 1973) provides policy and agency responsibilities for a Federal Government-wide standardization program. This includes the definitions for the different types of data element standards, such as International Standards, American national Standards, Federal General Standards, Federal Program Standards, Agency Standards, Unit Standards, and De facto Practices. The key policy statement is that "approved standards will be implemented by all Federal agencies in all circumstances where technical, operating and economic benefits can be expected to result" (FIPS PUB 28, 1973, p.4).

d. *Operations Standards*

GUIDELINES FOR ADP PHYSICAL SECURITY AND RISK MANAGEMENT (FIPS PUB 31; June, 1974) provides guidance and can be used as an evaluation checklist for computer system physical security.

GUIDELINE ON COMPUTER PERFORMANCE MANAGEMENT: AN INTRODUCTION (FIPS PUB 49; May 1, 1977) provides overall guidance to automated data processing (ADP) managers for meeting end-user requirements while managing and planning for ADP resources.

GUIDELINES FOR THE MEASUREMENT OF INTERACTIVE COMPUTER SERVICE RESPONSE TIME AND TURNAROUND TIME (FIPS PUB 57; August 1, 1978) provides a methodology for measuring interaction times and describes other functional performance measures.

GUIDELINES FOR ADP CONTINGENCY PLANNING (FIPS PUB 87; March 27, 1981) provide broad, generic information to assist information system managers in the preparation of contingency plans.

APPENDIX C: DESCRIPTION OF IEF ™ TOOLSETS

This appendix provides an overview of the graphical modeling tools available within each toolset in the Texas Instruments' Information Engineering Facility™ (IEF™) Computer Aided Software Engineering (CASE) tool. The four toolsets are the Planning Toolset, the Analysis Toolset, the Design Toolset, and the Construction Toolset. The tools used to interface with the Central Encyclopedia are also addressed.

A. Planning Toolset

A strategic top-down approach typically begins with the Information Strategy Planning stage using the Planning Toolset. During this stage, the Planning Toolset supports the conceptual model definition of the information architecture, the business system architecture, and the technical architecture.

1. Data Modeling - Subject Area Diagrams (DM)

Data modeling entails building a global data model, graphically depicting a business's principal subject areas. The subject areas can be subdivided into high level entity types in an entity-relationship (ER) model, but this step is usually performed during the Business Area Analysis phase.

2. Activity Hierarchy - Function Hierarchy Diagram (AHD)

The Function Hierarchy Diagram tool graphically models business activities at their highest level; these activities are generally the principal functions performed by the business.

3. Activity Dependency - Function Dependency Diagrams (ADD)

This tool documents the functional sequence based on the dependencies between functions, such as logic and timing constraints. This diagram is also described as a high-level of abstraction data flow diagram, with the capability to represent sequential, parallel, recursive, multiple-enabling, and mutually exclusive dependencies.

4. Organizational Hierarchy (OHD)

The Organizational Hierarchy tool diagrams the existing organizational structure, and can create multilevel organizational charts.

5. Matrix Processor - Business Function/Entity Type Matrix (MTX)

The Matrix Processor builds high-level interaction models between the data model objects and the functional model objects. IEF™ provides over 40 standard matrices for collecting, analyzing, and clustering this information. A matrix is automatically populated by IEF™ when the data is available from the use of the other tools; a planner can also directly enter the information in the matrix.

6. Matrix Definition (MDF)

This tool functions like the Matrix Processor, but allows a planner to create customized matrices.

B. Analysis Toolset

Companies may skip the Information Strategy Planning phase and simply take a tactical approach by starting in the Business Area Analysis stage. During this phase a specific area of the overall business is analyzed in detail. Analysts develop three components for each business area: a data model, an activity model, and an interaction model. These can simply be subsets of the models developed using the Planning Toolset, or built from scratch if the Information Strategy Planning phase was omitted. Therefore, many of the tools are the same as those in the Planning Toolset.

1. Data Modeling - Entity Relationship Diagram and Entity Hierarchy Diagrams (DM)

Analysts use this tool to develop the Subject Area Diagram for a particular area of the business, and create (or refine) an ER diagram. Entities are subdivided into entity subtypes. The underlying characteristics of the entity types -- attributes -- and the properties of the relationships -- cardinality and optionality -- are added to the diagrams.

2. Activity Hierarchy - Process Hierarchy Diagram (AHD)

Analysts use this tool to develop and refine the high-level functional hierarchy diagrams into more detailed process hierarchies, resulting in elementary processes.

3. Activity Dependency - Process Dependency Diagram (ADD)

Analysts use this tool to expand the functional dependency diagrams by modeling the dependencies between lower level processes.

4. Action Diagram - Process Action Diagram (PAD)

IEF™ will automatically create a Process Action Diagram (PAD) for each elementary process in the business area. The PAD details the steps within processes, summarizing how elementary processes view entities and how they affect entities. The statements created provide the detailed process logic which is the basis for code generation. Analysts can also manually insert statements into the PAD, and IEF™ will prevent syntax, semantic, or spelling errors.

5. Structure Chart (SC)

The Structure Chart tool provides analysts a way to see the inter-relationships between Process Action Diagrams in a hierarchical manner.

6. Action Block Usage (ABU)

This tool simply provides the analyst with a graphical view of the hierarchical list of Process Action Diagrams.

7. Matrix Processor - Elementary Process/Entity Type Matrix (MTX)

Analysts use the Matrix Processor tool to define the effects of elementary processes on entity types, and to further define the business systems. The techniques used are the same as those used with the Matrix Processor in the Planning toolset.

8. Matrix Definition (MDF)

As in the Planning toolset, this tool provides a capability to create customized matrices.

9. Business System Definition (DBS)

This tool provides a method for defining business systems in preparation for the next phase. The objective of using this tool is to group elementary processes into business systems, ranked by priority.

C. Design Toolset

IEF™ supports two stages of the information engineering methodology with the Design Toolset: Business System Design and Technical Design. System designers use this toolset to determine implementation details, such as procedure flows, user screen formats, and data base management systems. The Design Toolset provides a number of automatic transformations of the business model which conceptually represent the physical implementation of the business systems.

1. **Dialog Flow - Dialog Flow Diagram (DLG)**

Designers use this tool to detail control and data flows between procedures and sequencing between user screens or other graphical user interfaces for on-line interactive systems, or sequence and flow of batch job steps for batch applications.

2. **Screen Design (SD)**

This tool provides designers a means to build screens for on-line applications. Recurring screen elements are the basis for building reusable templates and global system defaults.

3. **Prototyping (PT)**

Designers can use this tool to demonstrate the screen views to potential end-users, who can preview the presentation and the flow between screens before the supporting logic is installed.

4. **Action Diagram - Procedure Action Diagram (PAD)**

This tool is similar to the Action Diagram tool in the Analysis Toolset, and is used to refine the detailed logic of procedures.

5. **Structure Chart (SC)**

This tool performs the same functions in this toolset as in the Analysis Toolset.

6. Action Block Usage (SBU)

This tool performs the same functions in this toolset as in the Analysis Toolset.

7. Data Structure - Data Structure Diagram (DSD)

This tool provides designers with a graphical representation of the physical data base layout in order to optimize the results of IEF™'s automatic transformation of earlier data diagrams.

D. Construction Toolset

IEF™ develops 100% of the source code in the target programming language for the target hardware (monitor/terminal) and the target data base management system. This toolset provides the designer the controls for this feature. The toolset also provides a means to test the full application after coding.

1. Interactive Diagram Testing

This tool provides the designer with the capability to perform high-level debugging at the action diagram level.

E. Central Encyclopedia Toolset

A set of integrated host tools provides coordinated access to the Central Encyclopedia, and allows centralized reporting and model distribution management.

1. Model Subsetting

This tool provides a means for multiple developers to share the same model without contention while still maintaining model integrity, by allowing model subset distribution.

2. Model Merge

This tool provides the mechanism to combine multiple model subsets into a single composite model.

3. Version Control

This tool permits developers to maintain multiple copies of the same model at different stages of development, testing, and production.

APPENDIX D: NPS ANALYSIS IEF ™ PRINTOUTS

This appendix provides the IEF™ system printouts in support of the Chapter IV analysis of the NPS enterprise.[9] The contents of each Tab is identified below:

TAB	DESCRIPTION
A	Organizational Hierarchy Diagram (AHD)
B	Top-Level Functions in Activity Hierarchy
C	Function vs. Organizational Unit Matrix
D	Subject Areas, Entity Types, Relationships
E	Entity-Relationship Diagram (Foldout)
F	Function vs. Entity Type Matrix
G	Entity Type vs. Organizational Unit Matrix
H	Function vs. Entity Type Matrix (Clustered)
I	Info System vs. Organizational Unit Matrix
J	Info System vs. Entity Type Matrix
K	Info System vs. Function Matrix
L	Entity Type and Entity Sub-type Attributes
M	Activity Hierarchy Diagram (AHD) Decomposition
N	Activity Definition Report

[9] This appendix has a separate, limited distribution due to its size. Copies of this appendix may be requested from the Naval Postgraduate School, Monterey, California, 93943-5000.

APPENDIX E: MIDDLEWARE TECHNOLOGY

This appendix provides a discussion of middleware, including a definition, a description of use, and selected examples of database middleware technologies and products.

A. MIDDLEWARE

The term middleware has many differing connotations. *Middleware* (or midware) can refer to architectures, languages, communications programs, or simply application programming interfaces (API)[10]. IS specialists primarily use the term when discussing client/server or distributed processing environments; most agree that middleware in this context is any software that provides a common method for accessing data from different types of Data Base Management Systems (DBMS) across a network (Oski, 1993; Byron, 1994; Paul and Richardson, 1994). Figure E.1 provides a graphical definition of middleware.

Some middleware products provide only limited or specific features; other products are more flexible and provide a full range of functions and services. Greater flexibility has a downside, which is loss in system performance. For example,

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[10] An Applications Programming Interface (API) is a set of function and call programs that allows a client application to intercommunicate with one or more server applications.

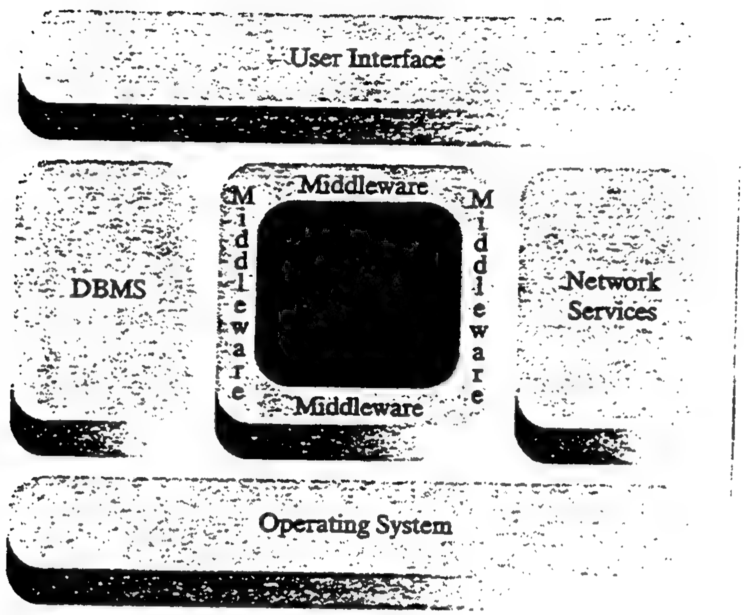

Figure E.1 Middleware
(IBI, 1993, p. 18)

the rigorous, real-time performance requirements of on-line transaction-processing (OLTP) systems often require database-specific middleware, which allows multiple different clients to access a specific DBMS; database-neutral middleware, which

allows a client to connect to a variety of DBMSs, can generally meet the performance requirements of a decision support system. One analyst asks:

> Should the database engine you choose dictate the method you use to access data, or should the clients' need to access data from a variety of databases take precedence? (Oski, 1994)

Middleware generally consists of three components: an API for one or more applications, one or more communications protocols, and one or more drivers. Three core technology categories of middleware exist: Remote Procedure Calls (RPC), Message Queuing Software (also known as Message Oriented Middleware, or MOM), and Object Request Brokers (ORB). (Paul and Richardson, 1994)

Remote Procedure Call (RPC) systems are integrated with naming and security services so that clients and servers can locate and identify each other, even in large distributed networks. RPCs use synchronous communications to execute a set of instructions on a remote machine, through what appears to be a local procedure call, and wait for a response. Because synchronous communications are used (i.e., the client sends a request and must wait for the response), fast network performance is critical to obtaining satisfactory response times when using RPC middleware. (Paul and Richardson, 1994; Spector and Eppinger, 1994)

The Open Software Foundation (OSF),a vendor consortium of major companies including IBM, Digital Equipment Corporation

(DEC), and Hewlett-Packard Company (HP), bases its proposed standard Distributed Computing Environment (DCE) on an underlying RPC transport framework. DCE is a framework built on an RPC transport mechanism which attempts to integrate numerous functions in a distributed processing environment. Currently defined features include Remote Procedure Calls (RPC), Threads, Directory Service, Distributed File System, Security Service, and Distributed Time Service components. RPCs, defined earlier, are the cornerstone of the DCE. *Threads* enable multiple client calls to be made to a process without loading the process multiple times, resulting in better performance and memory use. The *Directory Service* is a store of the names of global and local resources. The *Distributed File System* provides users with a common file system across different operating systems. The *Security Service* maintains a security database for each cell (local grouping of users and systems) which provides authentication and security access rights based on the Massachusetts Institute of Technology's (MIT) Kerberos security program. The *Distributed Time Service* synchronizes all the host clocks on the system. Additional planned features provide greater functionality and additional services. Figure E.2 provides a graphical depiction of the DCE architecture. (Gallagher, 1994; Bozman, 1994)

Message Queuing Service middleware products use high-level APIs and asynchronous communications to pass information.

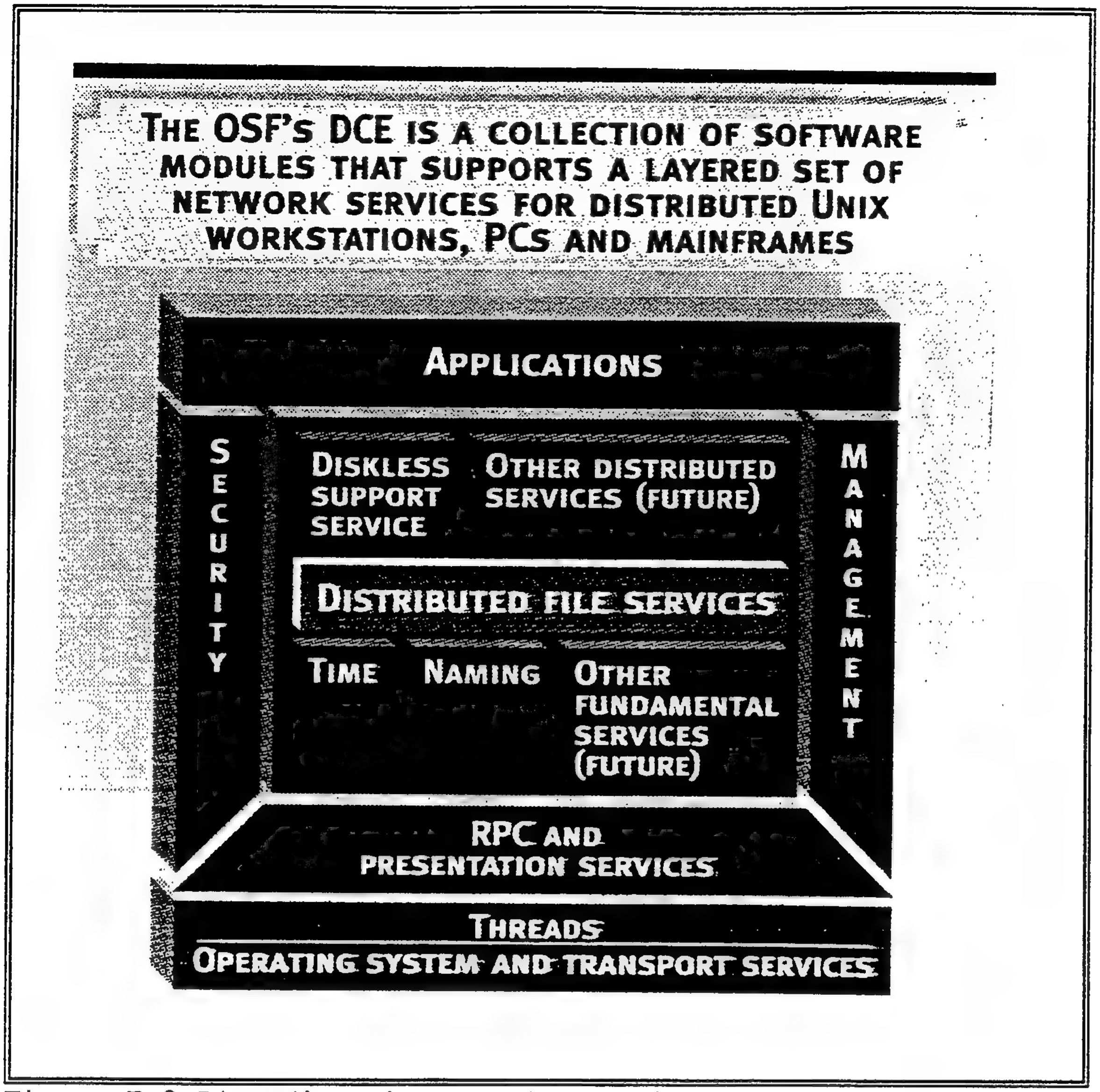

Figure E.2 Distributed Computing Environment Architecture (Bozman, 1994)

These products use queues to transfer data: client queues hold the initial requests, which transfer across the network whenever an opportunity window opens; and server queues hold the arriving requests; the response returns through the queues in reverse order. Queues log or hold messages, support delivery acknowledgement, priority handling, and content

translation between platforms. Since asynchronous communications are used, the client can continue processing while waiting for the response to a request; this provides the message queuing method with a significant advantage over the REC method. Since queues are used, no constraints on the application structure exist, i.e., a queue can send a message to one, many, or all queues, and vice versa. (Yeamans, 1994; Paul and Richardson, 1994)

Object Request Brokers (ORB), a product of object-oriented programming and development, manage the exchange of messages between objects across a network. ORBs generally use RPCs as an underlying transport mechanism for managing interactions, and support high-level APIs. The Object Management Group (OMG), a vendor consortium, defines standards for ORBs in the Common Object Request Broker Architecture (CORBA). In CORBA, clients send requests to an ORB, which locates the server, forwards the request, receives the reply, and returns the reply to the client. Using a standard Interface Definition Language (IDL), a client can access any server independent of server location, operating system, platform, or server programming language. (Siegel, 1994; Paul and Richardson, 1994)

These three technologies provide the underlying support for many different categories of middleware, including:

1. Network middleware
2. Database middleware

3. Conversion middleware

4. Graphical User Interface (GUI) middleware

5. Software development middleware

Network middleware allows application developers to build applications which can communicate at any network layer; this category can use any of the three middleware technologies. *Database middleware* provides mechanisms for accessing and manipulating data in a remote database. Database middleware consists primarily of Structured Query Language (SQL) interfaces between databases. Some people even claim that relational DBMSs (RDBMSs) and object-oriented DBMSs (OODBMSs) can be considered database middleware. *Conversion middleware* includes products which perform transparent conversion of text, graphics, and other data elements used in applications. Conversion middleware is bundled with some database middleware for interfacing some DBMSs that allow multiple data types. *GUI middleware* provides an application using different GUIs access to a single application data source. An example of a GUI middleware is terminal emulation software for a specific application. *Software development middleware* consists of CASE-like tools and other fourth-generation programming language (4GL) tools that can shorten development time.

Database middleware products encompass the primary form of middleware that would be used in a client/server or distributed data processing information architecture. Numerous vendors provide database middleware products today;

they are too numerous to list and describe here. A brief description of selected examples provides an overview of the database middleware field. Examples of products based on SQL include Microsoft Corporation's Open Data Base Connectivity (ODBC); the IBM, Novell, WordPerfect Corporation, and Borland International Inc. consortium's Independent Database Application Programming Interface (IDAPI); and Apple Computer Inc.'s Data Access Language (DAL). Other types of approaches include *gateways*, such as Information Builders Inc.'s Enterprise Data Access/SQL (EDA/SQL); *protocols*, such as IBM's Distributed Relational Database Architecture (DRDA) and ISO's Remote Database Access standard (RDA); and *frameworks* such as Object Systems' Distributed Object Integration Tool (DOIT). Some middleware, such as Forrester Research Inc.'s "data switches", is purely theoretical. The following sections further describe these example approaches.

1. Structured Query Language (SQL)

Since many database middleware products are based on the Structured Query Language (SQL), at least a brief discussion of SQL is in order. SQL, originally developed by IBM in the 1970s under the name SEQUEL, is currently the *de facto* as well as the *de jure* accepted standard data access language for use with relational and distributed databases. Many variants, or dialects, of SQL exist due to vendor-specific extensions of the basic standard; the differences in

functionality can be significant, and render two SQL dialects incompatible. The American National Standards Institute (ANSI) and the International Standards Organization (ISO) jointly endorse a specific version of SQL as a standard, known as ANSI/ISO SQL; the standard is reviewed and updated on a periodic basis. The other most common version is known as IBM or DB2 SQL, or ANSI SQL with DB2 extensions. ANSI SQL is also a designated Federal Information Processing Standard (FIPS 127 series).

SQL is not a full-application development language; it is a data access language. SQL has three components for manipulating data and performing queries in relational databases:

1. A *data definition language* for creating relational tables, creating indexes to data, and defining fields of data.

2. A *data manipulation language* for entering information into a database and accessing and formatting the data.

3. A *data control language* for handling security functions. (Sprague and McNurlin, 1993, p. 216)

SQL is also a non-procedural transform-oriented language, meaning an input consisting of one or more relations (tables) is manipulated (transformed) into a single relation output.

A new SQL-based API, *Call Level Interface (CLI)*, is the current project of a vendor consortium known as the SQL Access Group (SAG). SAG's CLI standardizes on a common set of programming subroutines to provide interoperability through a standard interface. A crucial element of the CLI API is the

client library, which contains the vendor-specific server's networking component and the vendor's SQL implementation. The CLI API definition includes the SAG's version of SQL, which is based on the 1992 ANSI/ISO SQL standard. SAG's CLI SQL includes several extensions, such as management of indexes, that are not currently in the ANSI SQL standard; however, CLI SQL is for the most part a subset of the ANSI SQL standard. The CLI definition is under review by numerous standards bodies, including the X/Open vendor group, ANSI, and ISO, and industry analysts expect CLI to be incorporated into the ANSI SQL standard in the future.[11] (Holt, 1994; Sprague and McNurlin, 1993, p. 216)

2. Open Data Base Connectivity (ODBC)

Microsoft Corporation's Open Data Base Connectivity (ODBC) is an industry-standard database protocol based on the snapshot (first of three) stage of the SAG's CLI API. ODBC allows client applications to access data from relational or flat file databases. But just as the SAG's CLI requires additional components for full implementation, ODBC also requires additional vendor-specific components, depending on the nature of the client, the network interface, and the database engine. The ODBC core components include:

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[11] Developers can obtain copies of the SQL Access Group's Call Level Interface (CLI) specification, which has been published as an X/Open Snapshot, Call Level Interface (CLI), for $70.00 by calling 603-434-0802.

1. A library of Remote Procedure Calls (REC) for connection to the server, execution of a request, and retrieval of data into the client.

2. A standard SQL syntax, based on the snapshot version of the SAG's CLI API.

3. A standardized set of error codes.

4. Standard mechanisms for connecting and logging on to servers.

5. A standard representation of data types.

The architecture of a system using ODBC would include:

1. An application at the client which can make ODBC calls to the ODBC Driver Manager.

2. A *Driver Manager* which loads data source drivers on behalf of the clients. (Under Microsoft's Windows, this is generally implemented as a *Dynamic Link Library (DLL)* component.) This is the heart of the ODBC scheme.

3. *Drivers* (vendor-specific) which process ODBC calls passed from the client, submit SQL requests to a specific data source, and perform any necessary SQL syntax translation to or from the ODBC standard syntax. (Under Windows, these are usually included in the DLL; under Macintosh System 7, drivers are implemented as Shared Library Management System objects.)

4. A *data source* (the server -- includes the DBMS, the underlying operating system, and the network interfaces). (Davies, 1993; Shaw, 1994)

ODBC drivers perform functions analogous to network printer drivers. ODBC defines two types of drivers, single-tier and multiple-tier. A *single-tier driver* processes both ODBC calls and SQL statements, while a *multiple-tier driver* only processes ODBC calls, and passes SQL statements to the DBMS query engine. In general, flat-file databases use single-tier drivers, and relational databases use multiple-

tier drivers. In order to avoid the weaknesses of a least-common-denominator approach typical of generic common-interface approaches, ODBC matches the varying power of any particular DBMS to the requirements of the application through the concept of driver capabilities and conformance levels.

All ODBC drivers must implement a minimum specified capability or functionality level, known as the Core functions level. The *Core* functions are 23 functions based on the SAG's CLI specification. The Core functions provide the following capabilities: connect and disconnect from the database, prepare and execute SQL statements, map parameters and result sets to and from the client database, commit and rollback transactions, and receive error information. Two additional categories, Level One and Level Two, provide extended functionality. Each category is a superset of the preceding category. Most commercially available ODBC drivers today only provide Level One functionality. *Level One* functionality provides these additional capabilities in 15 functions: connect to the DBMS using DBMS-specific dialog boxes, get basic systems catalog information (metadata), get driver capabilities (metadata), send and retrieve long parameter and result values (includes Binary Large Objects, or BLOBs), and get and set statement and connection options. Full Level Two functionality provides 54 functions. *Level Two* functionality includes these additional capabilities in 16 functions: browse available connections and data sources, send and retrieve

arrays of parameter and result values, retrieve parameter count and describe parameters, use scrollable cursers to browse and update, get enhanced catalog information, and international character support.[12] (Intergraph, 1994; Satterfield, 1993; Maloney and Archer, 1994)

ODBC drivers also differ in the level of SQL they support; ODBC defines three levels of SQL conformance: Minimum, Core, and Extended. The *Core level* is equivalent to the SQL Access Group's CLI specification syntax. The *Minimum level* is a subset of the Core level which is primarily designed for use with single-tier drivers. The *Extended level* provides features that go beyond the CLI specification. Higher levels provide more fully implemented Data Definition and Data Manipulation Language (DFL and DML) support. (Intergraph, 1994; Satterfield, 1993)

ODBC also provides three levels of data type conformance, categorized with the same levels as SQL conformance. ODBC drivers do not need to match the data type conformance level to the SQL syntax conformance level, and typically do not, as third-party vendors frequently provide more extensive data type support with reduced SQL grammar implementations. (Satterfield, 1993)

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[12] An Intergraph White Paper, ***Intergraph ODBC Drivers***, dated May 5, 1994, provides an excellent description of the functions in each ODBC function category, as well as descriptions of the different SQL and data type conformance levels.

An ODBC application adapts itself to the capabilities of whichever DBMS it happens to be connected to at the moment. Therefore, the ODBC designers take the approach that the front-end (application) developer (and not the driver developer) should make design and implementation decisions regarding application behavior when certain DBMSs features are unavailable due to different conformance levels.

3. Independent Database Application Programming Interface (IDAPI)

The Independent Database Application Programming Interface (IDAPI) is a data access API promoted by the vendor consortium of IBM, Novell, WordPerfect, and Borland. IDAPI is also based on the SQL Access Group's CLI specification, but goes far beyond the CLI specification's functionality by adding 81 additional functions, including a number of DBMS-specific calls for Borland's navigational DBMSs. The key functionality provided by IDAPI is the ability to transparently access not only relational and flat-file databases (like ODBC) but also navigational databases[13], such as those developed by Borland for use on PCs (dBASE, Paradox). The method used by IDAPI consists of a two-part API with a supporting runtime environment. One part of the API deals

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[13] A navigational database uses a model where data is stored as a series of records. Individual data elements are accessed by "navigating" through a collection of records until the desired data is found. This is the model used by DBMSs implemented on PCs, such as Btrieve, dBASE, Paradox, and others. (Q+E, 1994, p.8)

with relational and flat-file databases using SQL-type commands; the other part of the API deals with navigational databases using specific navigational commands. Many of the issues surrounding IDAPI technology and implementation remain a mystery because IDAPI is not yet available for use by developers. However, some aspects of the IDAPI framework are available.[14] (Kernighan, 1993; Rymer, 1993)

The IDAPI architecture is relatively straightforward. In the simplest form, a client application makes an IDAPI function call to the IDAPI Object Layer, which passes the call to the IDAPI SQL Driver. If necessary, the IDAPI SQL Driver translates the call to a native call the target DBMS understands. The "IDAPI Technology" consists of an Object Layer, a Service Layer, and the SQL Driver.

The *Object Layer* is the core of the IDAPI technology, and is designed to manage the IDAPI environment, including information about available databases and database drivers. This layer receives calls from the client application and handles them, making its own calls to drivers, local database engines, and the IDAPI service modules. The Object Layer also manages client application sessions, by allocating resources and initiating, terminating, and switching sessions. Finally, the Object Layer provides error-handling support.

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[14] Developers interested in more information about IDAPI can request the draft IDAPI specification by fax (408-439-9343). Requests for information can also be phoned to 800-344-4394 or 408-431-5209.

Complementing the Object Layer is the *Service Layer*, which consists of a number of service modules, including an Operating System Module, a Language Module, and a buffer management service. These modules provide implementation portability; one can simply replace one module with another corresponding module when porting IDAPI to another system. The *Operating System Module* provides the operating system-specific functions, such as file input/output (I/O) and memory management. The *Language Module* provides multiple character sets for support of different languages. The buffer management service module simply centralizes buffer management throughout the environment. Additional support includes in-memory table management, cache BLOB data management, and data record sorting. The *SQL Driver* provides the translation between navigational calls and SQL calls through emulation of navigational functions. (Kernighan, 1993)

IDAPI has a total of 106 functions, which are broken down into ten functional categories:

1. Environment and Connection (17)
2. Resources and Capabilities (3)
3. Catalog and Schema (3)
4. Statement Preparation and Execution (17 - 14 of which are SAG CLI specification functions)
5. Data Definition (11)
6. Data Manipulation (30)
7. Transaction Management (2)

8. Error (1)

9. DBMS or O/S Specific (21)

10. Composite (1)

Some of these functions are defined as specific to particular non-relational DBMSs, and therefore provide little or no functionality to SQL database users. (Kernighan, 1993)

IDAPI has three design configurations: IDAPI as a client, IDAPI as a server, and IDAPI as an integration server. As a client, IDAPI generates native DBMS calls through its drivers to be passed over the network to the database servers. As a server, IDAPI processes IDAPI calls and handles the communication of results and errors using all the network's protocols. As an integration server, IDAPI acts like a hub, integrating the communications with multiple DBMS servers. (Kernighan, 1993)

IDAPI middleware provides other important programmer and user services. One of the most useful of these expected services is the ability to perform cross-database operations, such as heterogeneous joins. IDAPI also allows simultaneous connection to multiple DBMSs, supports the placement of multiple "bookmarks" on each cursor, and supports scrollable cursers.

IDAPI designers claim IDAPI will support ODBC by providing an IDAPI driver that treats ODBC as another native

database; however, the proposed version of IDAPI does not support all the ODBC function calls, so incompatibility remains an issue.

4. Other Data Access Methodologies

Other methodologies for accessing data from heterogeneous databases across a network exist, but are not as widespread or supported throughout industry as ODBC (or even the non-existent IDAPI).

a. Data Access Language (DAL)

Apple Computer Inc.'s DAL[15] is an ANSI SQL-based database access product that connects Macintosh and Windows (through ODBC) client applications with 12 different databases across a wide variety of server platforms. DAL uses a single API -- Microsoft's ODBC. In addition to full support for ODBC, accessible through Macintosh's Data Access Manager APIs, DAL provides 15 function calls for non-ODBC implementations. The DAL SQL dialect includes extensions for procedure support and data type mapping, and is translated to/from target DBMSs SQL dialects by the DAL Server component. (Independence Technologies, Inc., 1994)

b. Enterprise Data Access/SQL (EDA/SQL)

Information Builders Inc.'s Enterprise Data Access/SQL (EDA/SQL) is a very powerful middleware product

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[15] Independence Technologies, Inc. actually provides and licenses the Data Access Language technology.

which provides front ends with access to relational, hierarchical, flat-file, and navigational databases through a single SQL API implementation. EDA/SQL currently provides support for over 50 different DBMSs and file structures residing on over 35 hardware platforms and operating environments. Figure E.3 shows EDA/SQL's interfaces.

EDA/SQL uses a multi-layered architecture that includes database-specific drivers, a universal SQL translator, network navigation and connectivity, and an API/SQL interface. Using RPC as an underlying transport mechanism, EDA/SQL is conceptually a gateway or hub server, with four functions: Locate, Secure, Warehouse, and Manage. The *Locate* function refers to the use and maintenance of a directory or catalog which helps provide request routing and distribution with location transparency. The *Secure* function refers to the ability to provide a single security authentication point at the EDA/SQL hub, down to the database field level. The *Warehouse* function supports data quality management as the data is transformed by installed business rules. The *Manage* function provides data and systems management and management related tools, including a query governor/statistics collector, data replication and copy management, and integrated GUI system administration and management. EDA/SQL gateways also exist for some specific DBMSs, including a high performance relational gateway for IBM's DB2 DBMS. EDA/SQL supports and provides standards

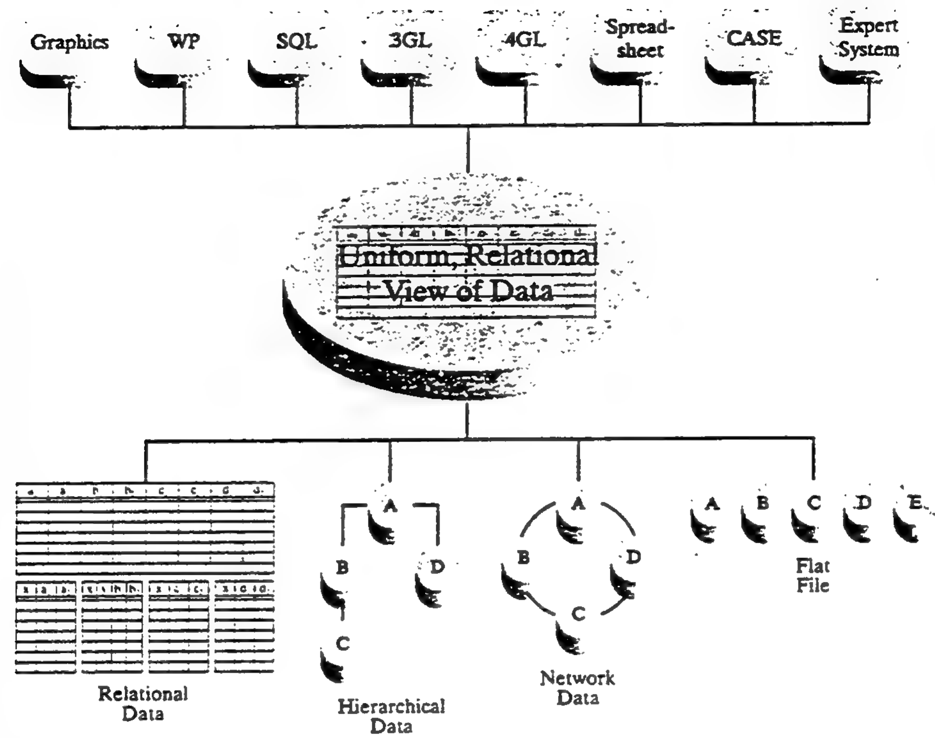

Figure E.3 IBI's Enterprise Data Access/SQL (EDA/SQL) (IBI, 1993, p. 2)

compliance with other industry activities, including the SAG's CLI, ODBC, DRDA, and DCE. (IBI, 1994; IBI, 1993, p. 2) Industry analysts believe that EDA/SQL's popularity has declined due to its single vendor distribution mode and the overshadowing popularity for Microsoft's ODBC (Gallagher, 1993).

c. Distributed Relational Database Architecture (DRDA)

IBM's native mainframe networking protocol is the System Network Architecture (SNA). IBM's *System Application Architecture (SAA)*, created in 1987, is a design specification for creating applications that can run on and access any IBM computer, regardless of the type of platform used for application development. Along with SAA, IBM's attempt to enter the client/server market is the Application Program-to-Program Communications (APPC) protocol, based on SNA, which runs on any IBM platform and allows applications running on one system to communicate with applications on other systems. The DRDA protocol is part of IBM's SAA, and describes how RDBMSs on different platforms can communicate with each other in a client/server mode. DRDA has the primary purpose of connecting LAN-based IBM databases to mainframe-based IBM databases (DB2). Other DBMS vendors also have licenses to build DRDA drivers, allowing LAN-based IBM databases to access their DBMS as well. DRDA's strengths are its support features for managing large systems; its principal weakness is lack of implementation. (Gallagher, 1993; Watterson, 1993, Salemi, 1993)

d. ISO Remote Data Access (RDA)

RDA is an ISO international standard for a common-protocol approach to remote data access. RDA provides a very limited generic implementation, using dynamic SQL, ANSI/ISO

SQL syntax, and the Open Systems Interconnect (OSI) protocol stack. Lack of support for the more common Transport Communications Protocol/Interconnection Protocol (TCP/IP) protocol stack currently prevents RDA's growth in industry. (Watterson, 1993)

e. Distributed Object Integration Tool (DOIT)

The Distributed Object Integration Tool (DOIT) is an attempt by Object Systems to define an integrated architecture, based on distributed object computing, that supports distributed data access without using APIs or drivers. DOIT offers a single platform for use with many diverse types of applications, providing an integrated comprehensive approach, and as such deserves mention. The DOIT product results from two requirements: the need to integrate data from heterogeneous systems in real time; and the need to be able to define data-access routines without using programming languages or APIs, based on the assumption that industry would not adopt a standard API for distributed data services. DOIT uses high-level graphical tools to define and access data sources, which are defined as objects through encapsulation.

The DOIT architecture contains three types of objects and a set of runtime services. The objects are: Data objects, Execution objects, and Manager objects. *Data objects* encapsulate data from a database, application, or other

source. These are the only objects visible to the user, and can be directly manipulated by the user, routed to other applications, or held in internal storage.

Execution objects are the internal structures that implement DOIT functionality. The five types of Execution objects are: Source (data source), Sink (data recipient), Filter (business rules), Trigger (events), and Notification (delivery methods). DOIT supports point-to-point, multicast, narrowcast, and broadcast modes of communications among objects.

Manager objects are the components of the runtime environment. The four Manager objects are: Object Integration Engine (OIE), Object Router, Persistent Storage Object, and the Object Browser. The *Object Integration Engine* is the heart of DOIT, and provides the control over all objects. The *Object Router* provides the linkages required among objects. The *Persistent Storage Object* provides a local storage location. The *Object Browser* is a front-end tool for identifying and manipulating objects present in the environment -- this allows the user to view the data encapsulated in an object.

The data sources are encapsulated by a *Legacy Application Wrapper (LAW)* using three methods of integration: file-level integration, I/O-level integration, and dynamic-data integration. File-level integration occurs when a LAW encapsulates an application's files. I/O-level integration

occurs when a LAW encapsulates an application's I/O interrupt. Dynamic-data integration occurs when a LAW encapsulates a standard application-integration protocol, such as Microsoft's Dynamic Data Exchange (DDE) or Object Linking and Embedding (OLE).

The DOIT environment can easily encompass the SAG's CLI specification and the OMG's CORBA architecture. DOIT can rely on CORBA as a standards-based Object Router, and can use SAG's CLI API as a LAW dynamic data integration standard. However, neither CORBA nor SAG's CLI provide equal functionality to DOIT. (Rymer, 1993)

f. Data Switches

A Forrester Research Inc. study report (1993) predicts that industry pressure will force ODBC and IDAPI to merge and form a single API standard. Even then, the merged standard does not provide the required performance. According to Forrester, what is needed are "data switches". *Data switches* are server software, created by database vendors, that control broad access to heterogeneous databases. Data switches, packaged as RDBMS extensions, have three functions: translation between heterogeneous DBMSs, administration, and provision of a global dictionary. (Eastwood, 1993)

APPENDIX F: REQUIREMENTS AND ALTERNATIVES ANALYSES METHODS

Systems Analysis and Design literature contains numerous discussions of the different methods for conducting requirements analysis; most of these methods generally have several points in common. Federal and DoD acquisition regulations also address requirements analysis, and provide specific guidance on minimum requirements. This appendix discusses the information system (IS) requirements and alternatives analyses guidelines found in the *Federal Information Resources Management Regulations* (FIRMR)(41 CFR 201), supported by the discussions in a supplemental guide published by the General Services Administration (GSA), *A Guide for Requirements Analysis and Analysis of Alternatives* (GSA-IRMS, 1990). The FIRMR identifies numerous factors to be considered during any IS requirements analysis; these are briefly outlined in the first section of this appendix. Similarly, the FIRMR includes several procedures for the conduct of the analysis of alternatives; these are briefly described in the second section of this appendix.

A. REQUIREMENTS ANALYSIS FACTORS

The purpose of a requirements analysis is to determine and document an organizational need for information processing resources. The FIRMR lists ten factors as the minimum issues

to be considered during an IS requirements analysis (41 CFR 201-20.103.1-103.10). These include:

1. Information Needs or Requirements

The information needs factor addresses a requirement for an organization to identify its information needs, taking into account all the possible internal and external considerations. Examples of these considerations include the organization's function or mission, available information sources, external information demands, record storage requirements, and information format.

The GSA guide provides a more detailed listing of factors to consider when determining information requirements, which expands on the FIRMR's list. The GSA guide also provides recommendations that go beyond the minimum requirements in the FIRMR. One such recommendation is that an organization should describe and define the current system in order to establish a baseline for identifying the future requirements. As part of this analysis of the current system, GSA recommends that the current system undergo a performance evaluation.

2. System Life

An organization establishes an expected information system life, from the point of view of the organization's use

of the resources (organizational lifetime), and from the point of view of potential reuse by another organization later (total lifetime).

3. Description of Requirements

The description of the requirements is obviously the key element in requirements analysis. This description generally has two parts: the basis for the requirements, in terms of mission needs; and the actual requirements, in terms of functionality and performance required. As part of the requirements definition process, an organization reviews all International, Federal, Department of Defense (DoD), and other Agency standards for applicability to each requirement.

The FIRMR also directs organizations to prevent less than full and open competition during the contracting phase due to unnecessarily restrictive requirements.

4. Compatibility-Limited Requirements

The FIRMR requires a formal justification for any requirements that restrict the hardware or software to components that must be compatible with existing Federal information processing (FIP) resources. The justification basis is an economic feasibility analysis of technical and operational requirements, or the risk and impact of a hardware or software conversion failure.

5. Justification for Specific Make and Model

The FIRMR also requires a formal justification for any requirements that list a specific "make and model" hardware or software component.

6. Security Requirements

The security requirements meet the security and privacy needs of the proposed system; these requirements include a discussion of the potential threats and hazards, the methods for protection against these threats, and additional physical and environmental safeguards.

7. Accessibility Requirements for Individuals with Disabilities

Accessibility requirements provide disabled personnel with equivalent access to electronic office equipment and telecommunication devices, in accordance with other Federal regulations.

8. Space and Environmental Requirements

The requirements for physical space and environmental support, such as heating and cooling, must be addressed within the requirements analysis.

9. Workload and Related Requirements

The description of predicted workload requirements is frequently one of the hardest factors to analyze, since it includes a projection of the processing, storage, data entry, communications, and support services requirements over the system's life. The discussion must also include expandability

requirements, contingency requirements, and a performance evaluation of the currently installed information processing resources.

10. Records Management Requirements

All the issues surrounding records management for Federal agencies, such as the use of the Standard and Optional Forms Management Program, must be included in the requirements analysis to ensure continued interoperability with other programs, and prevent duplication of effort.

B. PROCEDURES FOR ANALYSIS OF ALTERNATIVES

The FIRMR directs organizations to consider several factors when attempting to identify and analyze the available alternatives that would meet the resource requirements. The basis for any alternatives analysis is the statement of requirements that results from the requirements analysis phase. Alternatives are compared and evaluated against this statement of requirements to determine the most advantageous alternative that meets the requirements.

1. Consideration of Alternatives

The guidance requires organizations to first conduct some form of market research to determine if the required technology is available, and identify potential candidates as feasible alternatives. The market analysis includes many

sources: vendor and industry contacts, trade shows, peer groups, published materials, and even requests for information (RFI).

Next, an organization must look at GSA's mandatory programs -- mandatory-for-use and mandatory-for-consideration -- to determine if any of these can meet the requirements. The GSA mandatory-for-use programs include: the FTS 2000 network to satisfy long distance telecommunications requirements, consolidated local telecommunications services, Purchase of Telephones and Services (POTS) program, the National Security and Emergency Preparedness (NSEP) program, and the Financial Management Systems Software (FMSS) Multiple Awards Schedule (MAS) Contracts program. Non-use of these mandatory-for-use programs requires a waiver from GSA.

The GSA mandatory-for-consideration programs include: the Federal Software Exchange Program (FSEP), the Excess FIP Equipment program, the Federal Secure Telephone Service (FSTS), and Information Systems Security (INFOSEC) services and programs, including Communications Security (COMSEC) systems and services.

Other alternatives to be considered include reusing Federal Information Processing (FIP) resources discarded by other organizations, sharing existing FIP resources, contracting for FIP resources, and using GSA's non-mandatory programs (single and multiple award schedule contracts) and assistance.

2. Cost for Each Alternative

The projected acquisition cost determines which cost analysis method must be used. If the expected cost is less than $50,000, only a simple cost/benefit analysis is required for each alternative under consideration. However, if the anticipated cost is greater than $50,000, the net present value of the total estimated cost of each alternative must be calculated and used during the analysis. The total estimated cost consists of the system life cost and any other costs that would be associated with that alternative, whether incurred before or after the system life timeframe. The total estimated cost includes costs attributed to the project in several related areas, including: personnel salaries and training costs, office supply costs, utility costs, maintenance costs, and site preparation costs.

The GSA guide includes a discussion of several non-cost functional and risk factors which should be considered as well. The functional factors include availability, reliability, maintainability, expandability, flexibility, security, privacy, personnel impacts, user acceptance, and accountability (audit). The risk factors are financial risks, technical risks, and schedule risks.

3. Conversion Analysis

Selection of a specific alternative often requires that other FIP resources may have to be converted (i.e., from

one programming language to another), replaced (i.e., from one hardware platform to another), or discarded. Therefore, a conversion analysis looks at the costs, risks, and size of any conversion required. The FIRMR provides a listing of expenses which should not be included as conversion costs; an example of a disallowed expense is the costs associated with purging duplicate or obsolete FIP software, data bases and files.

4. Obsolescence Analysis

This analysis ensures that an organization has developed a strategy to prevent FIP resources from becoming obsolete before the end of projected system life.

5. Capability and Performance Validation

The FIRMR requires that an organization conduct a capability validation and a performance validation of each alternative as part of the process of evaluation. Each organization determines the actual techniques to be used in the validation process.

Capability validation is the technical verification that the proposed alternative meets the functional requirements. The capability validation process does not evaluate or measure any performance characteristics; that is left for the performance validation. Techniques used for capability validation range from contacting other users of the proposed resource to full vendor or organizational operational capability demonstrations of the system's functionality.

Performance validation is the technical verification that the proposed alternative can handle the specified workload within the specified performance time constraints. The tested workload includes both present and projected workload volumes. Examples of performance validation techniques are: timed execution of existing applications and data, simulation modeling, stress testing, benchmarking, and acceptance testing.

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